NOAA California Energy Security Project

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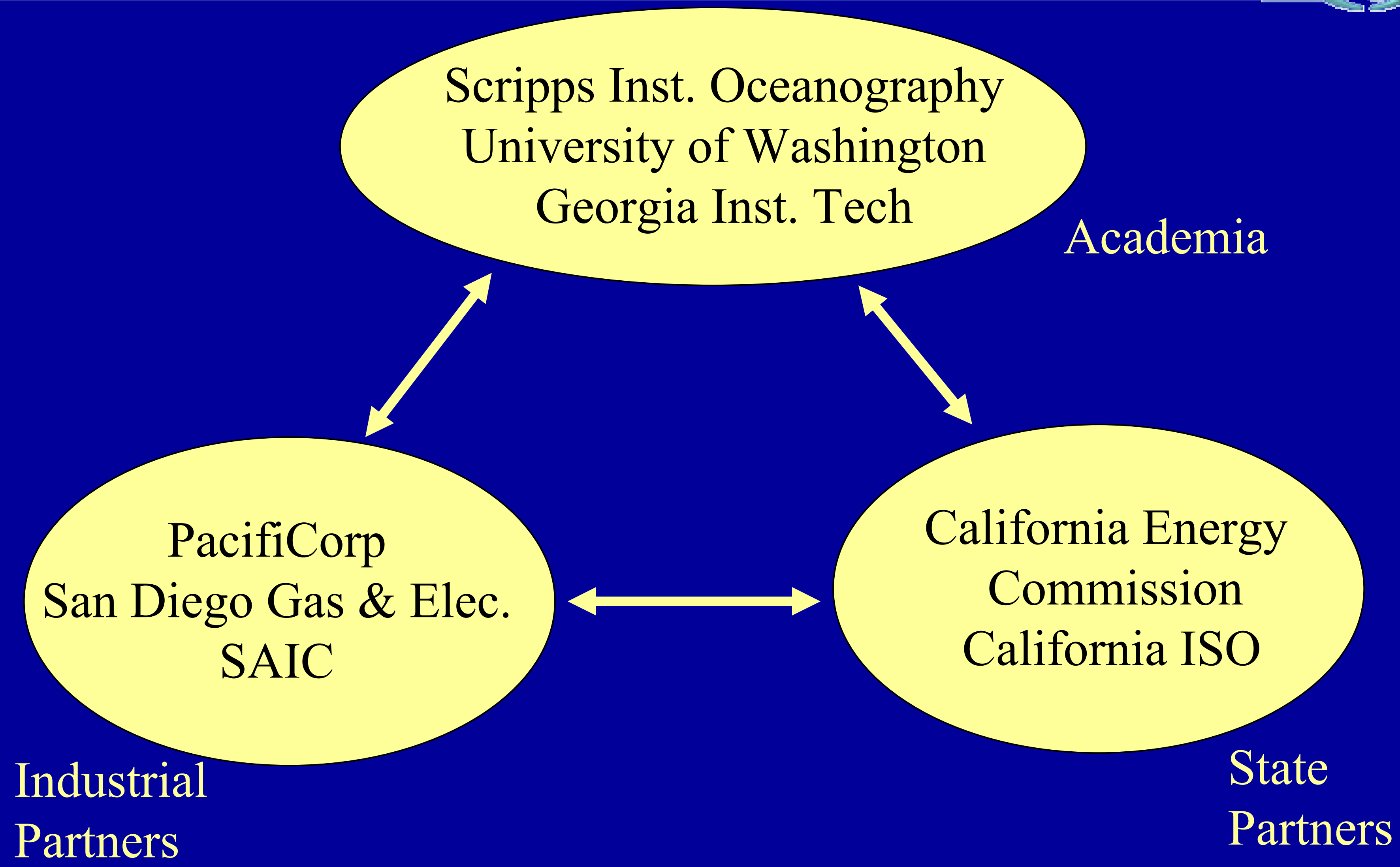
Project Overview



Project Objective

Determine the economic value of climate and weather forecasts to the energy sector

Why aren’t climate forecasts used?

- Climate forecasts are *probabilistic in nature* – sometimes unfamiliar to the user
- *Lack of understanding* of climate forecasts and their benefits
- *Language and format* of climate forecasts is hard to understand – need to be translated for end-users
- *Aversion to change* – easier to do things the traditional way

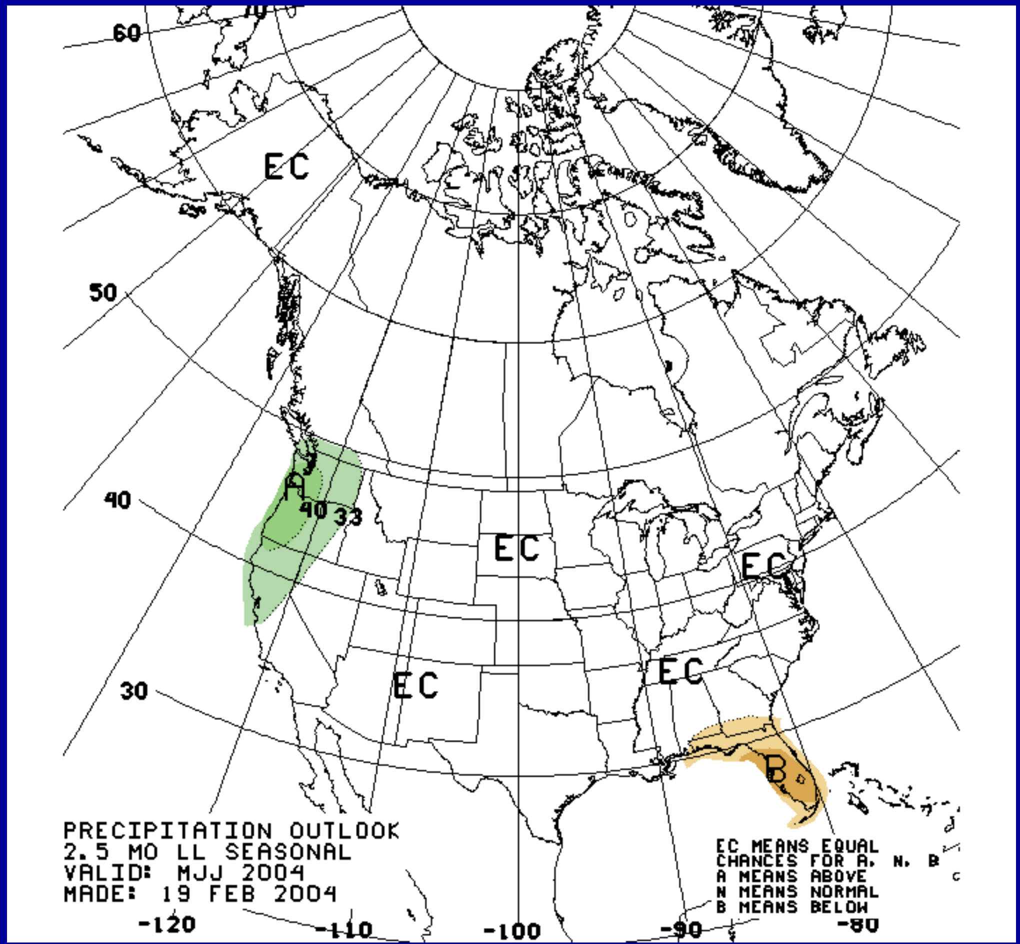
CPC Seasonal Outlooks

Climate Outlook

The key below is used to interpret each of the color versions of the ***Climate Outlook*** products. In areas where confidence in predictive skill has been established, the probabilities of the above normal, near normal or below normal categories are increased accordingly above the Climatology level of 1/3 (33.3%) for each category. These probabilities are contoured using colors as depicted in the key below.

In those areas where the skill of our present prediction tools is not sufficient, the default is equal chances (white color). The probabilities of experiencing each of the three categories (above normal, near normal or below normal) remain equally likely (1/3) in the white areas on attached maps.

Precip	Temp	Probability anomaly as shown on map	Probability of occurrence for each Equal: A	N	B	Most likely category
		40%-50%	73.3%-83.3%	23.3%-13.3%	3.3%	"Above"
		30%-40%	63.3%-73.3%	33.3%-23.3%	3.3%	"Above"
		20%-30%	53.3-63.3%	33.3%	13.3%-3.3%	"Above"
		10%-20%	43.3-53.3%	33.3%	23.3%-13.3%	"Above"
		5%-10%	38.3-43.3%	33.3%	23.3%-28.3%	"Above"
		0%-5%	33.3-38.3%	33.3%	33.3%-28.3%	"Above"
		0%-5%	30.8%-33.3%	33.3%-38.3%	30.8%-33.3%	"Near Normal"
		5%-10%	28.3%-30.8%	38.3%-43.3%	28%.3-30.8%	"Near Normal"
		0%-5%	33.3%-28.3%	33.3%	33.3%-38.3%	"Below"
		5%-10%	28.3%-23.3%	33.3%	38.3%-43.3%	"Below"
		10%-20%	23.3%-13.3%	33.3%	43.3%-53.3%	"Below"
		20%-30%	13.3%-3.3%	33.3%	53.3%-63.3%	"Below"
		30%-40%	3.3%	33.3%-23.3%	63.3%-73.3%	"Below"
		40%-50%	3.3%	23.3%-13.3%	73.3%-83.3%	"Below"
		0%	33.3%	33.3%	33.3%	"Equal Chances"



Importance of Stakeholder Involvement

- Identify potential uses and benefits of forecast information
- Develop forecasts to meet user needs
- Deliver and discuss products with stakeholders
- Obtain feedback from stakeholders and iterate
- Integrate forecasts with decision-making

Key stakeholder questions

- What types of forecast information could help with decision-making?
- What are the specifications for desired forecasts?
- What are the organizational incentives and barriers to forecast use?
- What are the potential benefits and costs of using the forecast information?

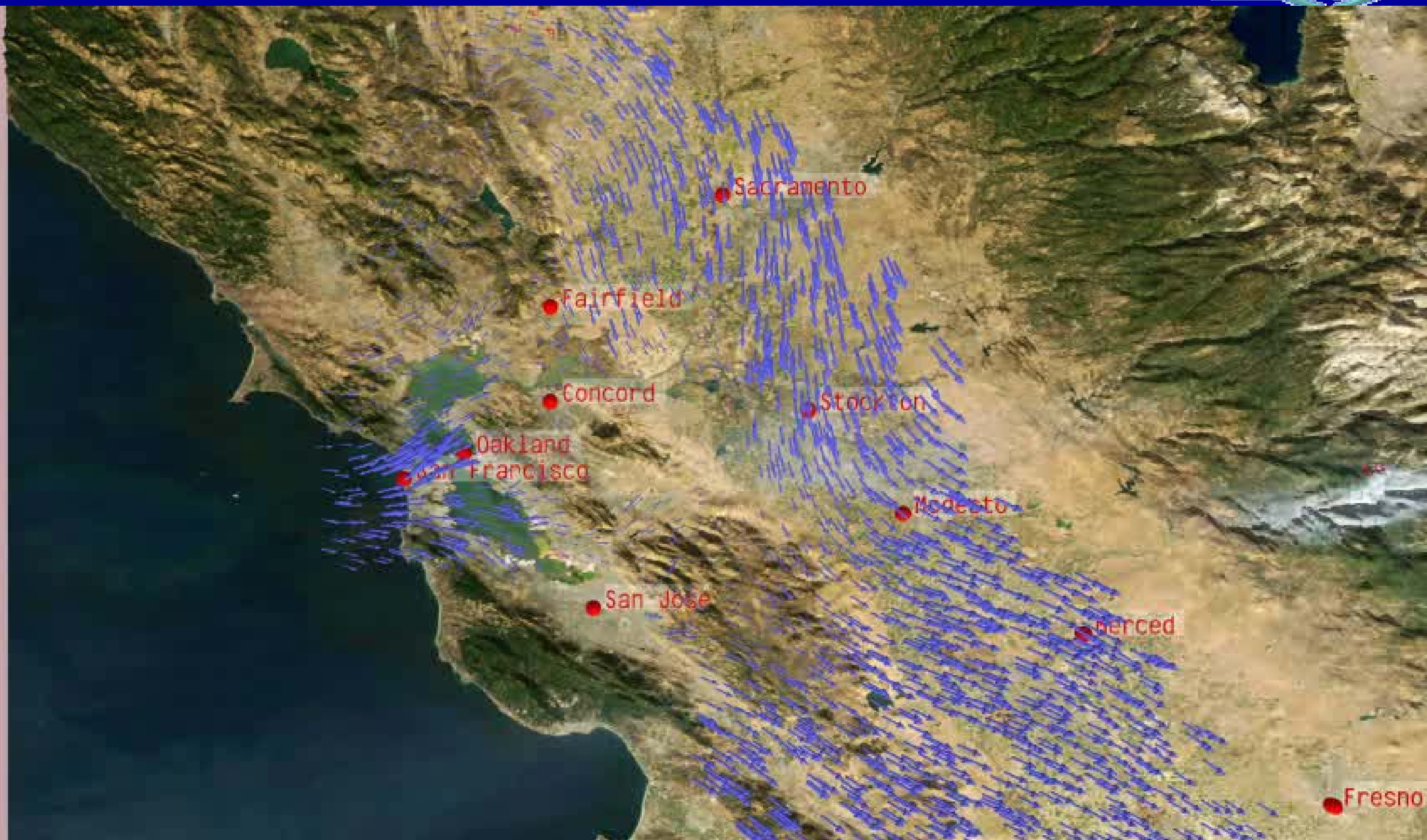
Case studies

1. California delta breeze
2. Peak day load forecasting
3. Irrigation pump loads
4. California summer temperatures
5. Hydropower

1. California "Delta Breeze"

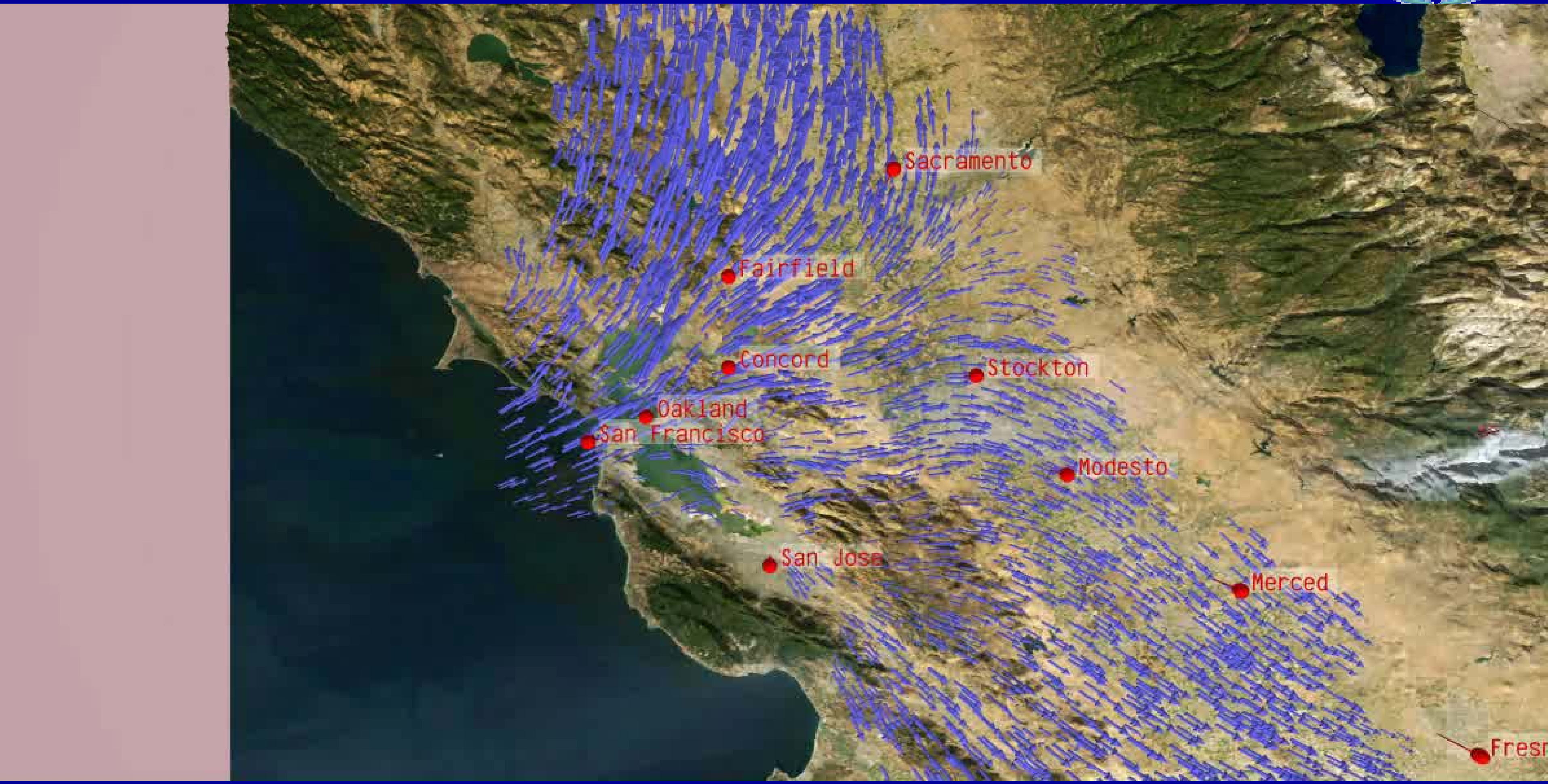
- An important source of forecast load error (CalISO)
- Big events can change load by 500 MW (>1% of total)
- Direct cost of this power: $250K/breeze day (~40 days/year: ~$10M/year)
- Indirect costs: pushing stressed system past capacity when forecast is missed!

NO delta Breeze



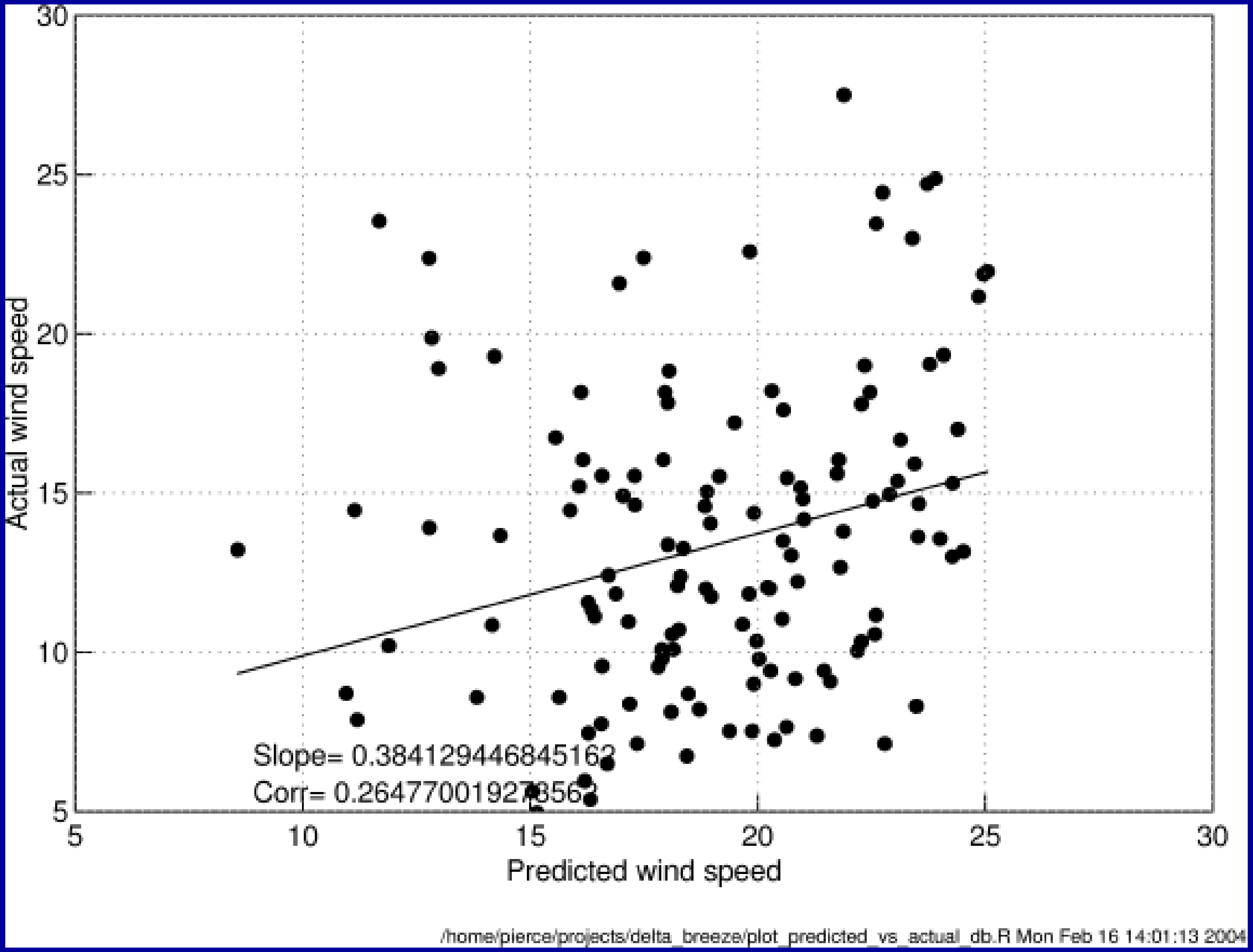
Sep 25, 2002: No delta breeze; winds carrying hot air down California Central valley. Power consumption high.

Delta Breeze



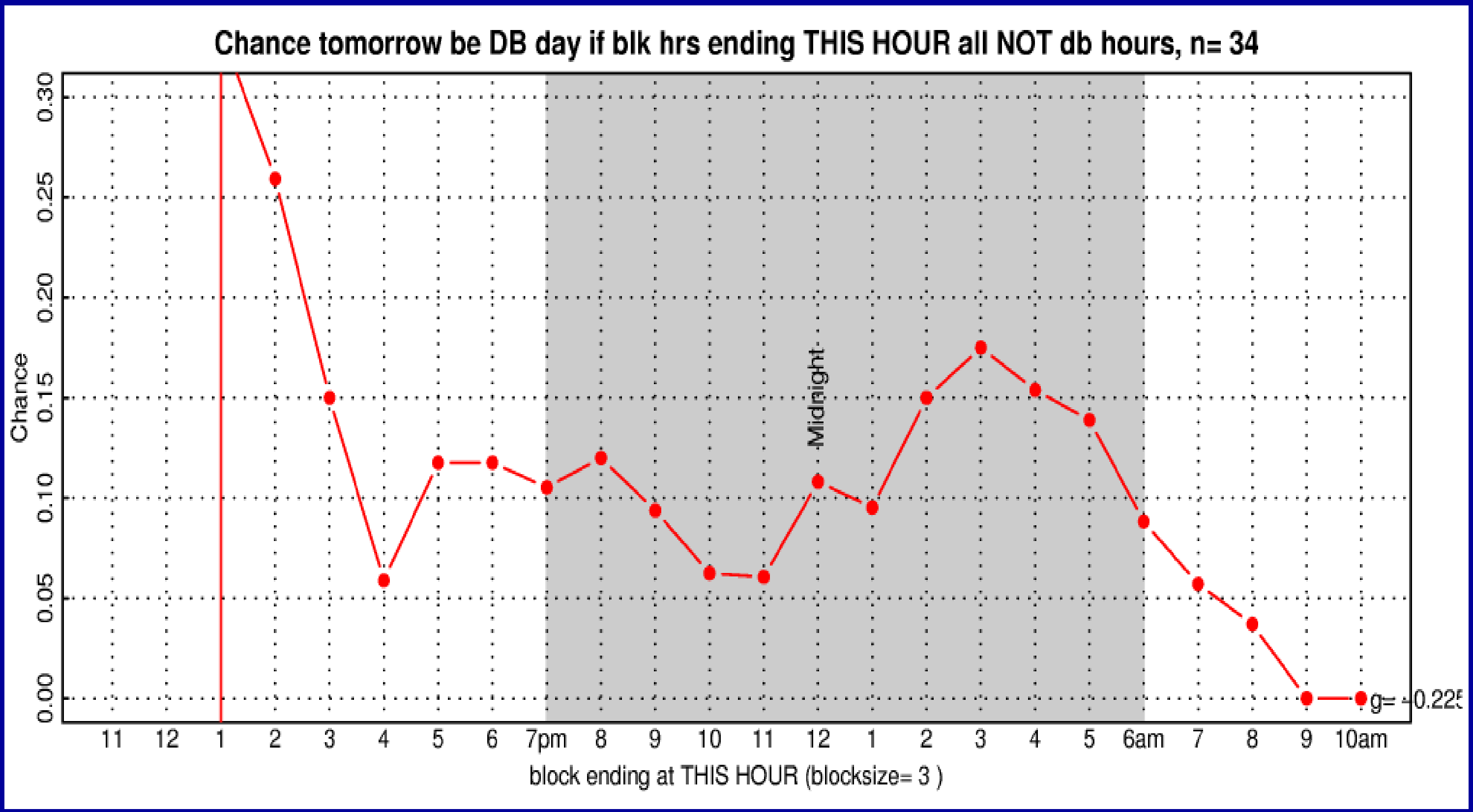
Sep 26, 2002: Delta breeze starts up; power consumption drops >500 MW compared to the day before!

Weather forecasts of Delta Breeze



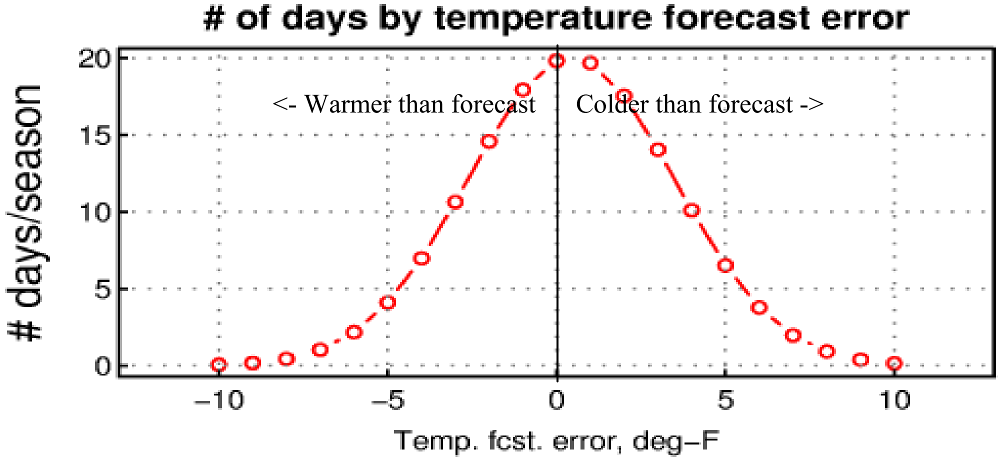
1-day ahead prediction of delta breeze wind speed from ensemble average of NCEP MRF, vs observed.

Statistical forecast of Delta Breeze



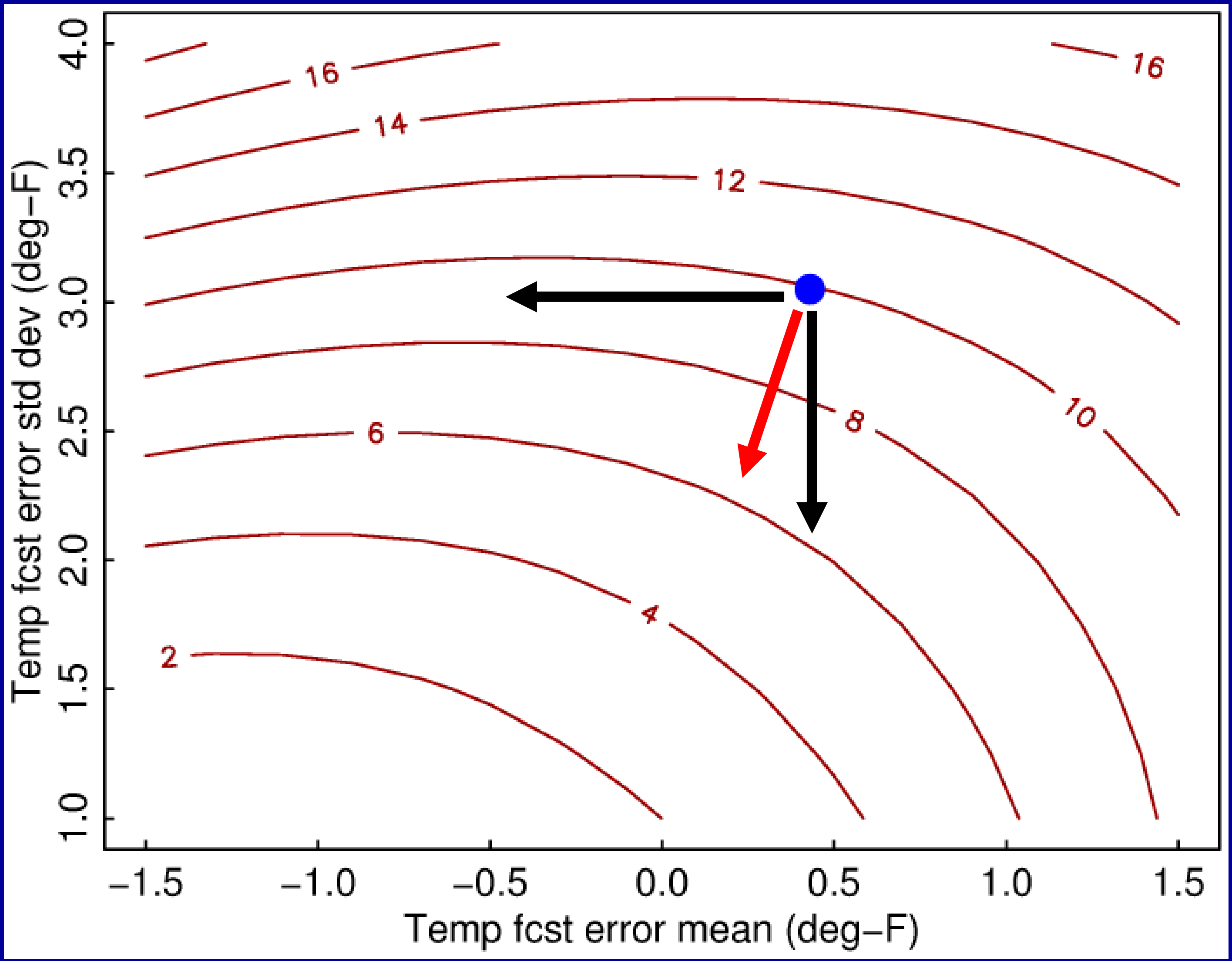
(Also uses large-scale weather information)

By 7am, can make a determination with >95% certainty, 50% of the time



Dennis Gaushell, Cal-ISO

Cost of forecast errors



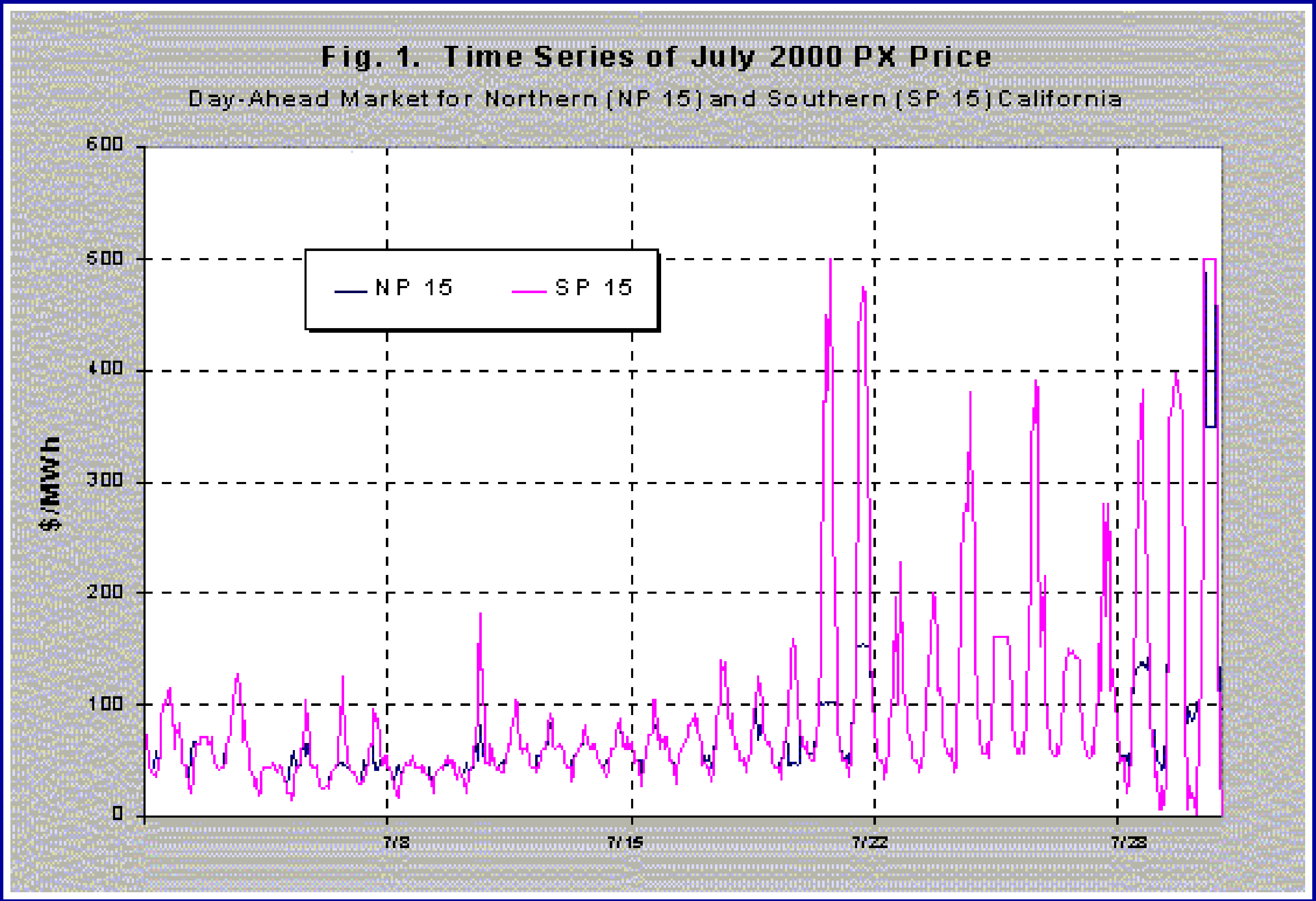
Delta Breeze summary

- Using climate information can do better than dynamic weather forecasts
- Possible savings of 10 to 20% in costs due to weather forecast error. Depending on size of utility, will be in range of high 100,000s to low millions of dollars/year.

2. Load demand management

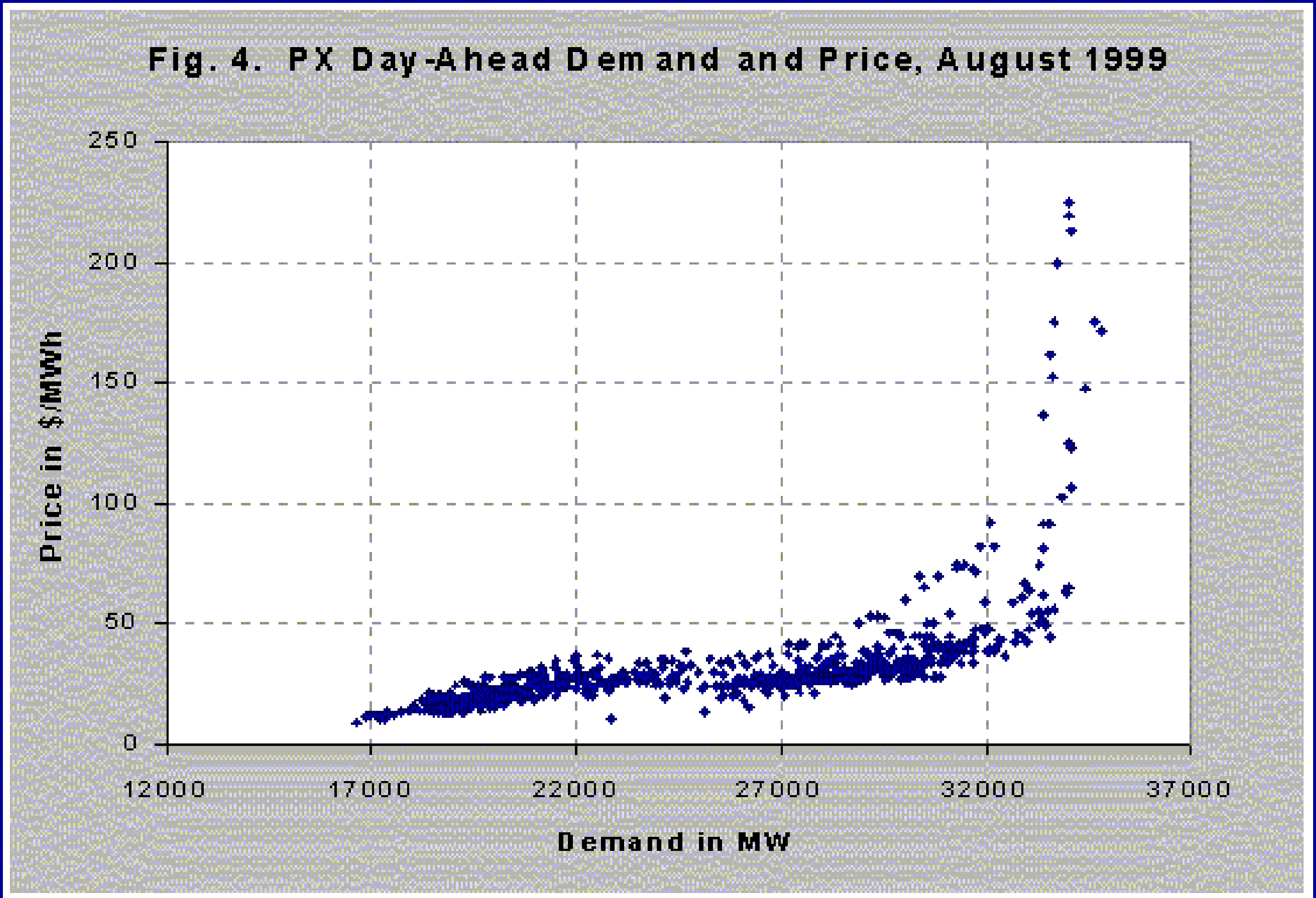
- Induce customers to reduce electrical load on peak electrical load days
- Prediction challenge: call those 12 days, 3 days in advance
- Amounts to calling weekdays with greatest "heat index" (temperature/humidity)

Why shave peak days?



http://www.energy.ca.gov/electricity/wepr/2000-07/index.html

Price vs. Demand



http://www.energy.ca.gov/electricity/wepr/1999-08/index.html

July

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
		1 2990 MW 79 F	2 3031 MW 81 F	3 3389 MW 88 F	4 2958 MW 85 F	5
6	7 2814 MW 71 F	8 2766 MW 73 F	9 2791 MW 75 F	10 2906 MW 79 F	11 3106 MW 83 F	12
13	14 3130 MW 76 F	15 3089 MW 74 F	16 3046 MW 84 F	17 3102 MW 77 F	18 2888 MW 78 F	19
20	21 3317 MW 82 F	22 2867 MW 73 F	23 3055 MW 77 F	24 2991 MW 73 F	25 3006 MW 75 F	26
27	28 2935 MW 78 F	29 3165 MW 82 F	30 3398 MW 86 F	31 3176 MW 78 F		

Average = 2916 MW

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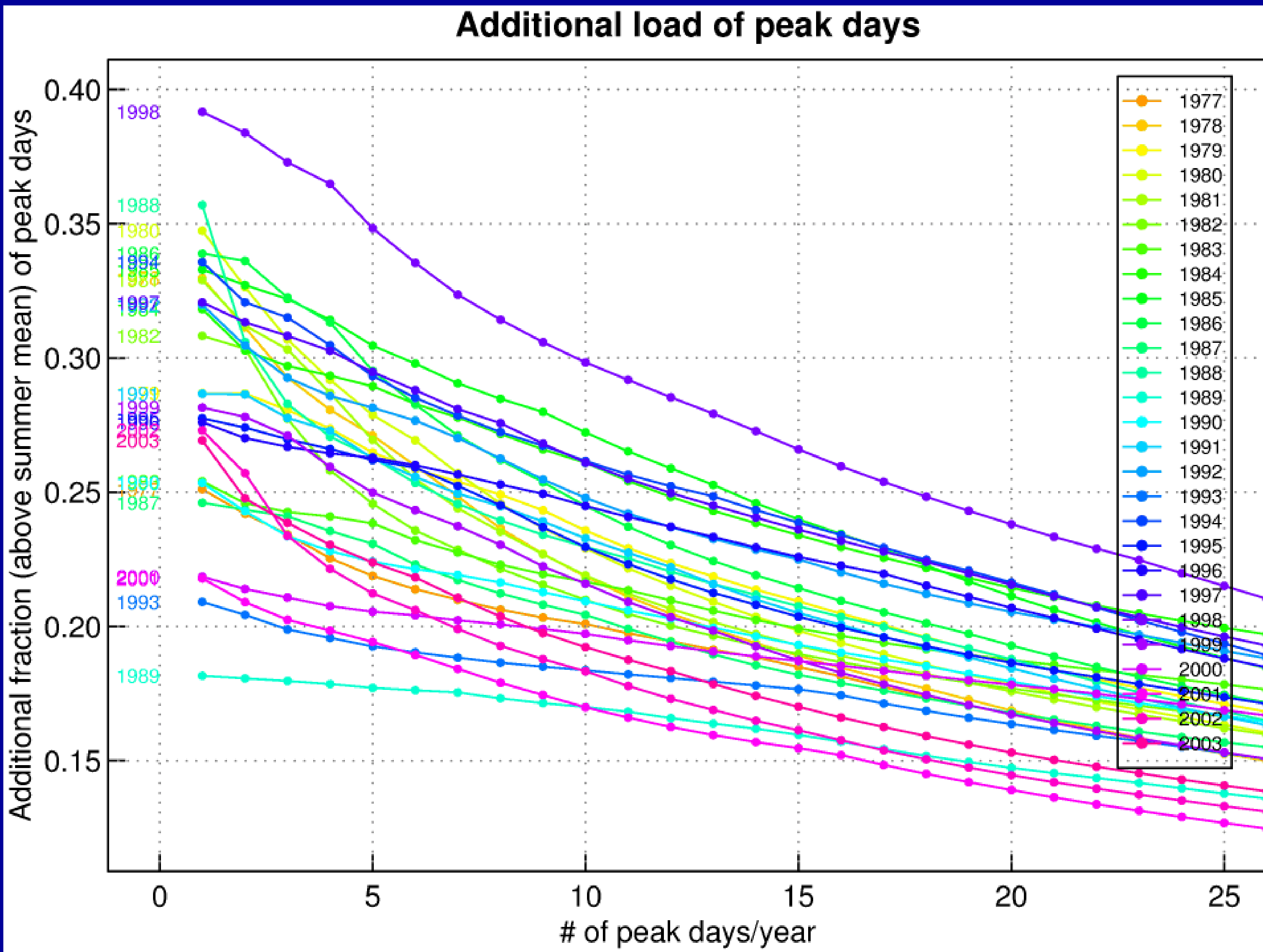
Average = 2916 MW   Top days = 3383 MW   (16 % more than avg)

Strong year to year variability



Peak day electrical load savings

- If knew *electrical loads* in advance: 16%

- With event constraints: 14%

(Load is relative to an average summer afternoon)

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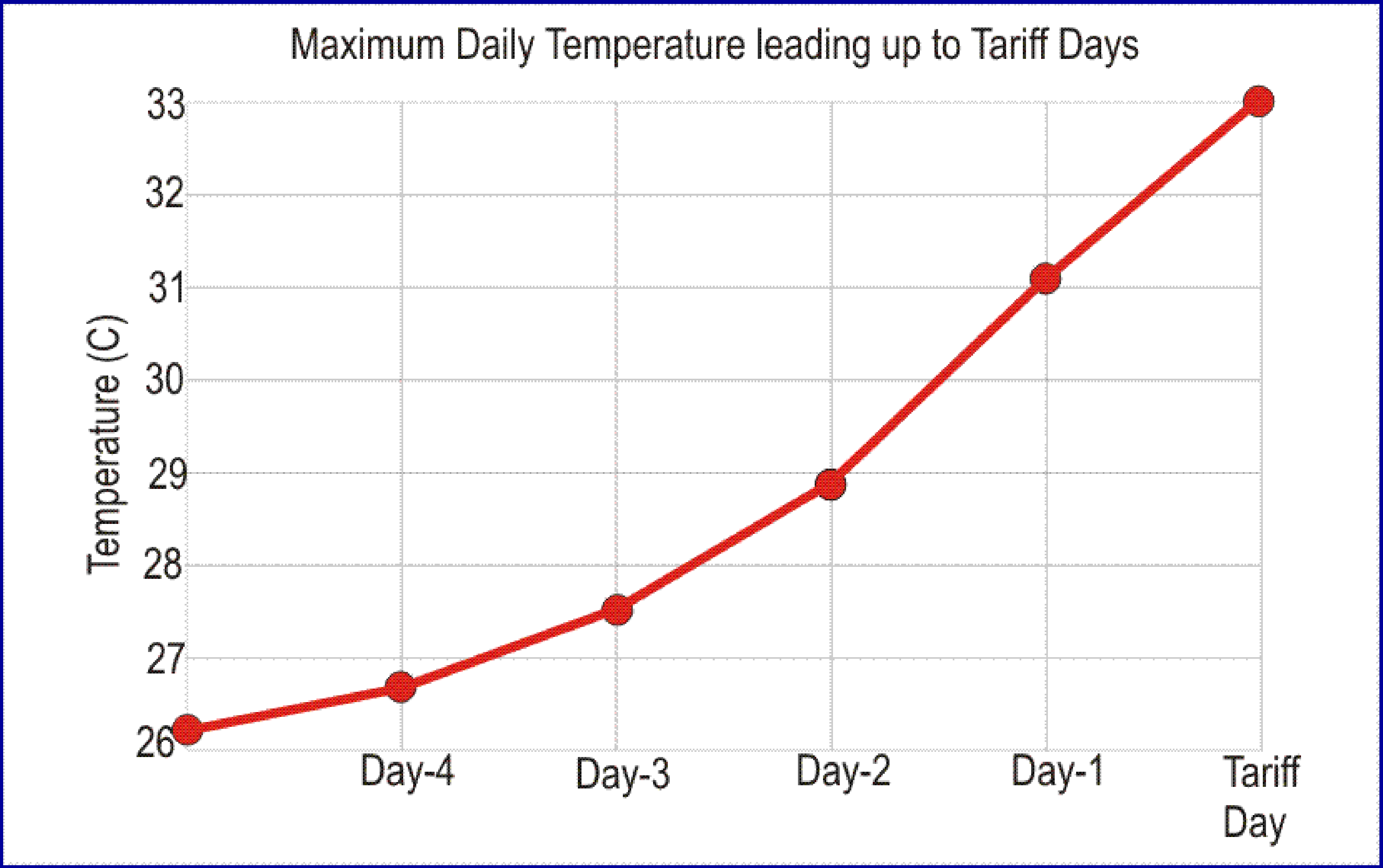
Average = 2916 MW Warm days = 3237 MW (11 % more than avg)

Peak day electrical load savings

- If knew *electrical loads* in advance: 16%
- With event constraints: 14%
- If knew *temperature* in advance: 11%

(Load is relative to an average summer afternoon)

What can climate analysis say?

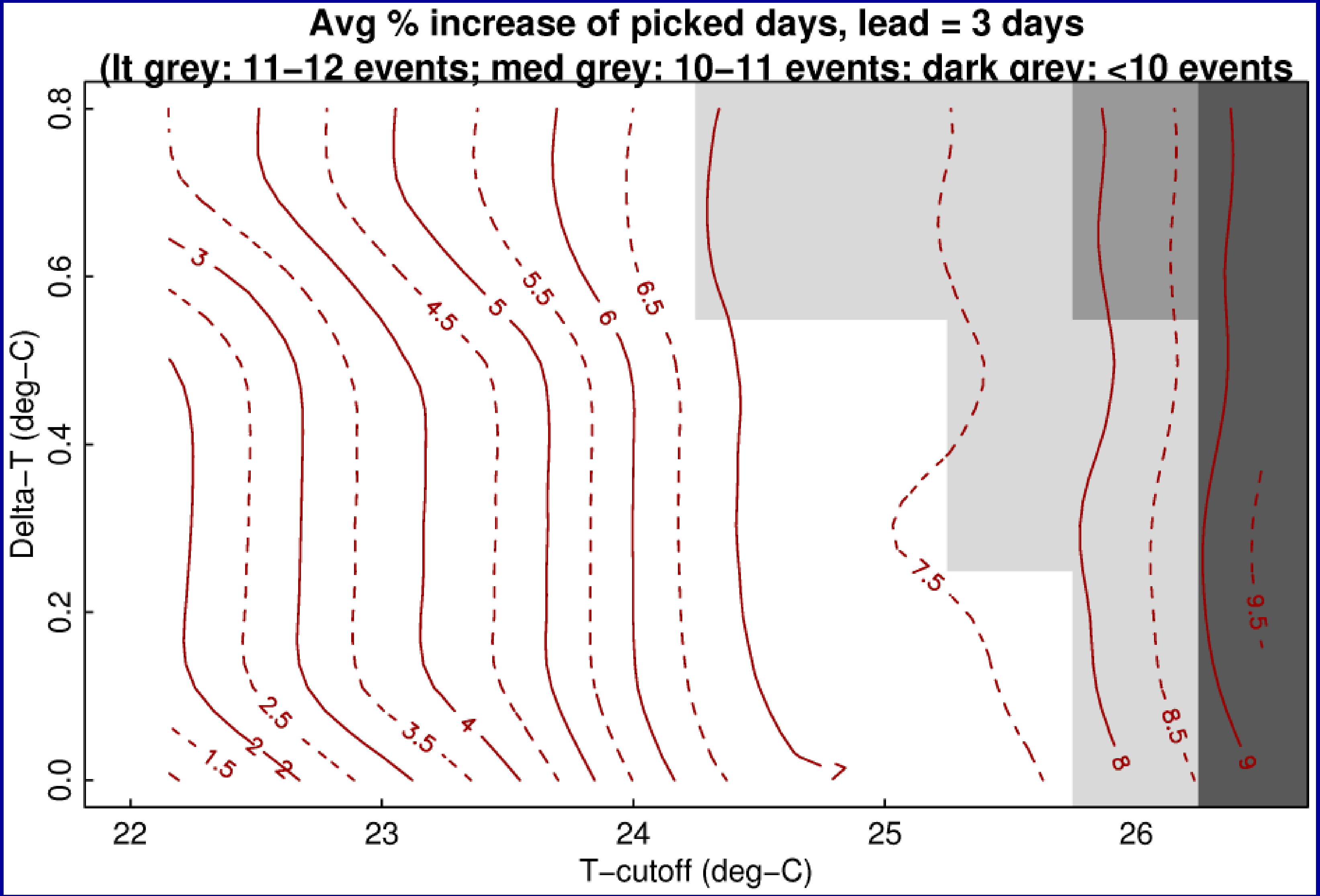


Peak day electrical load savings

- If knew *electrical loads* in advance: 16%
- With event constraints: 14%
- If knew *temperature* in advance: 11%
- Super simple scheme (24C, 0.5): 6%

(Load is relative to an average summer afternoon)

Optimizing the process



Peak day summary

- Might ultimately be a *real-time* program
  - Driven by "smart" electric meters
  - Main benefit would be avoided cost of peaker generation plants ~$12M/yr.

- Until then, climate prediction:
  - Far less deployment cost
  - Cost of avoided procurement ~$1.3M/yr

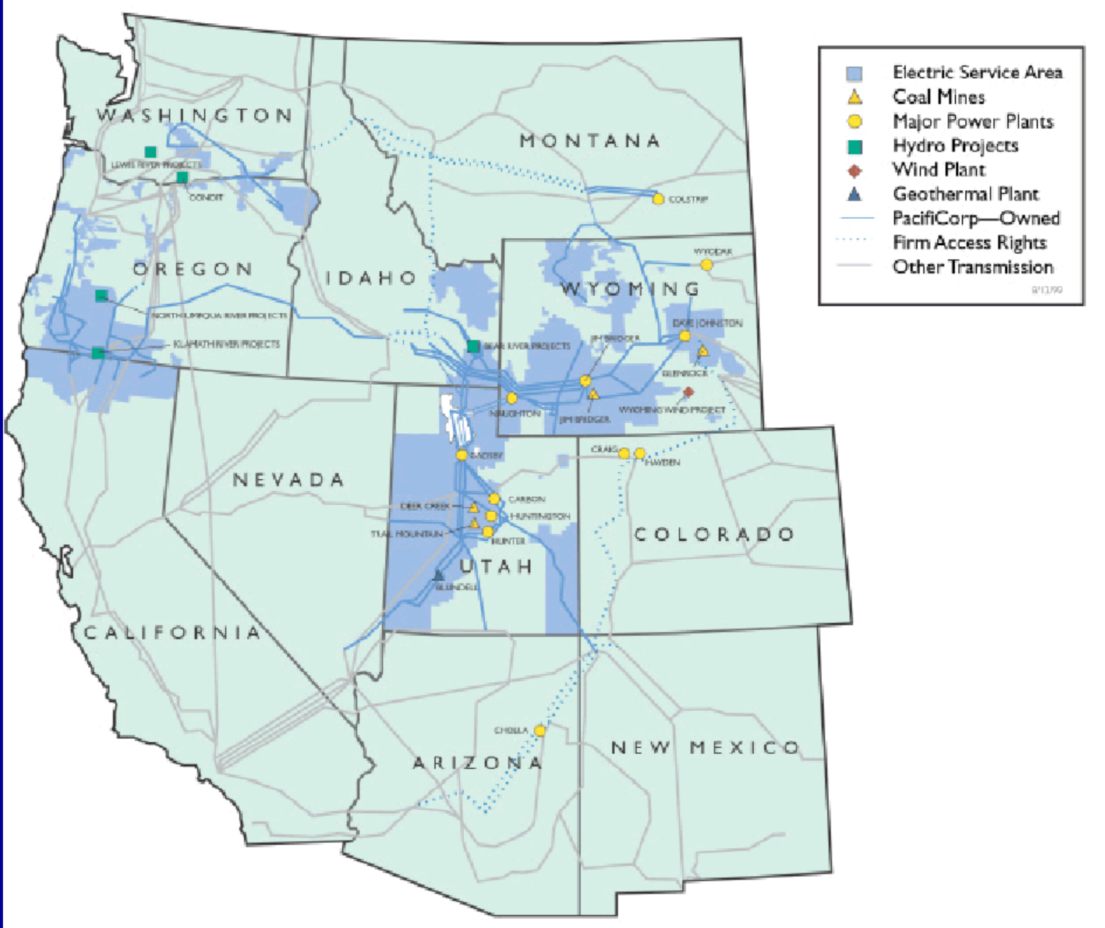
-> Climate analysis can give expected benefits to a program

3. Irrigation pump loads

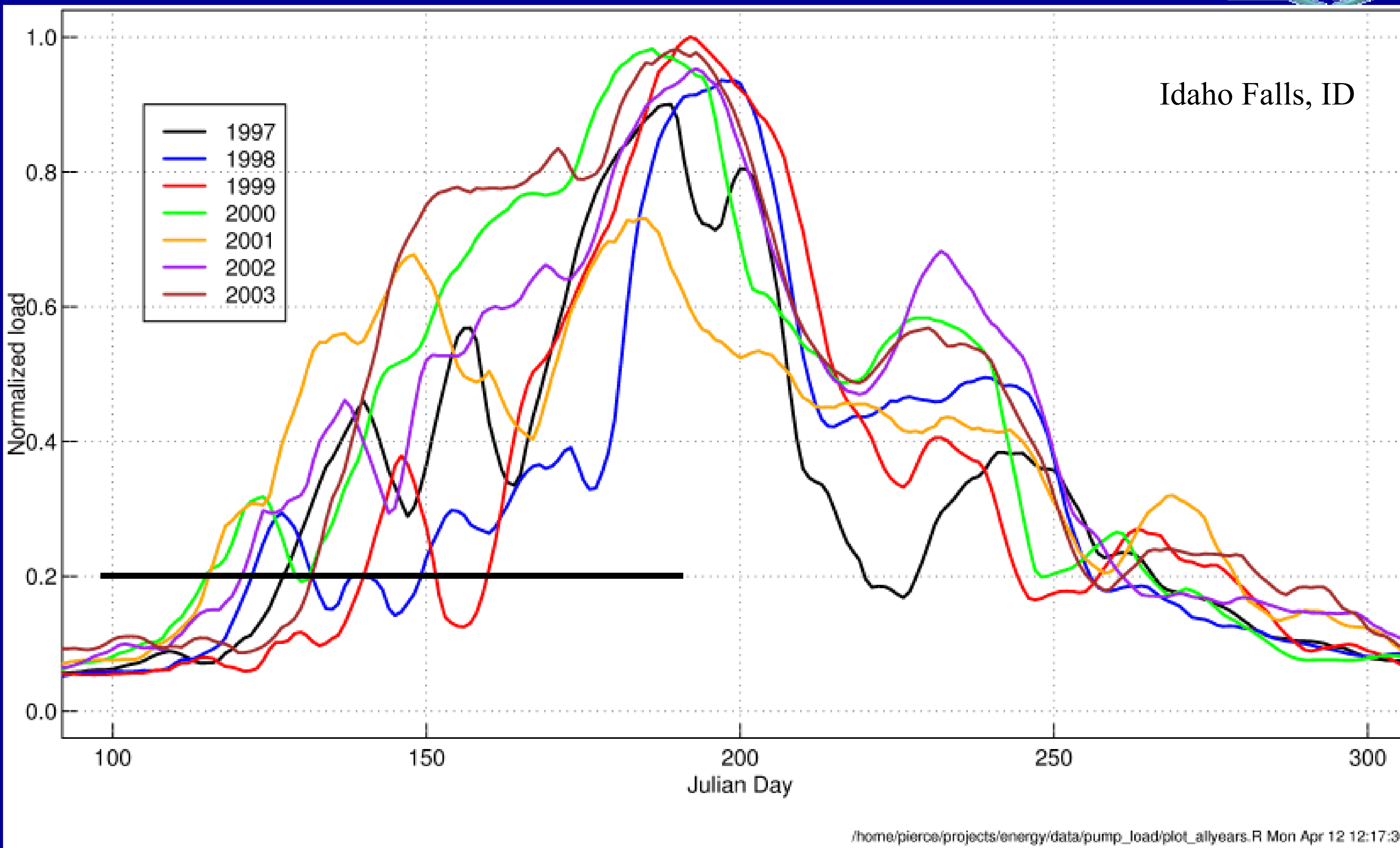
- Electricity use in Pacific Northwest strongly driven by irrigation pumps

- When will the pumps start?

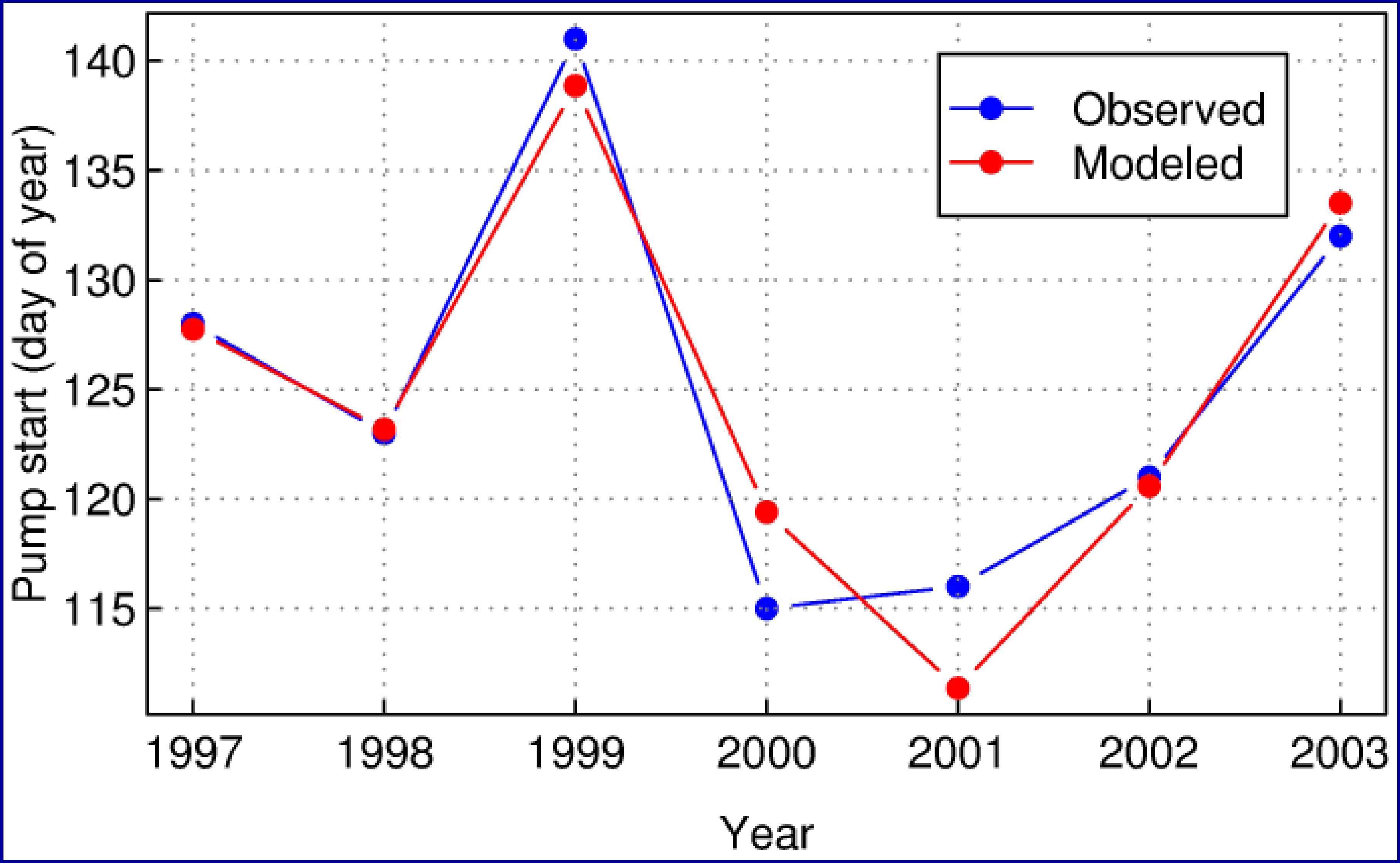
- What will total seasonal use be?



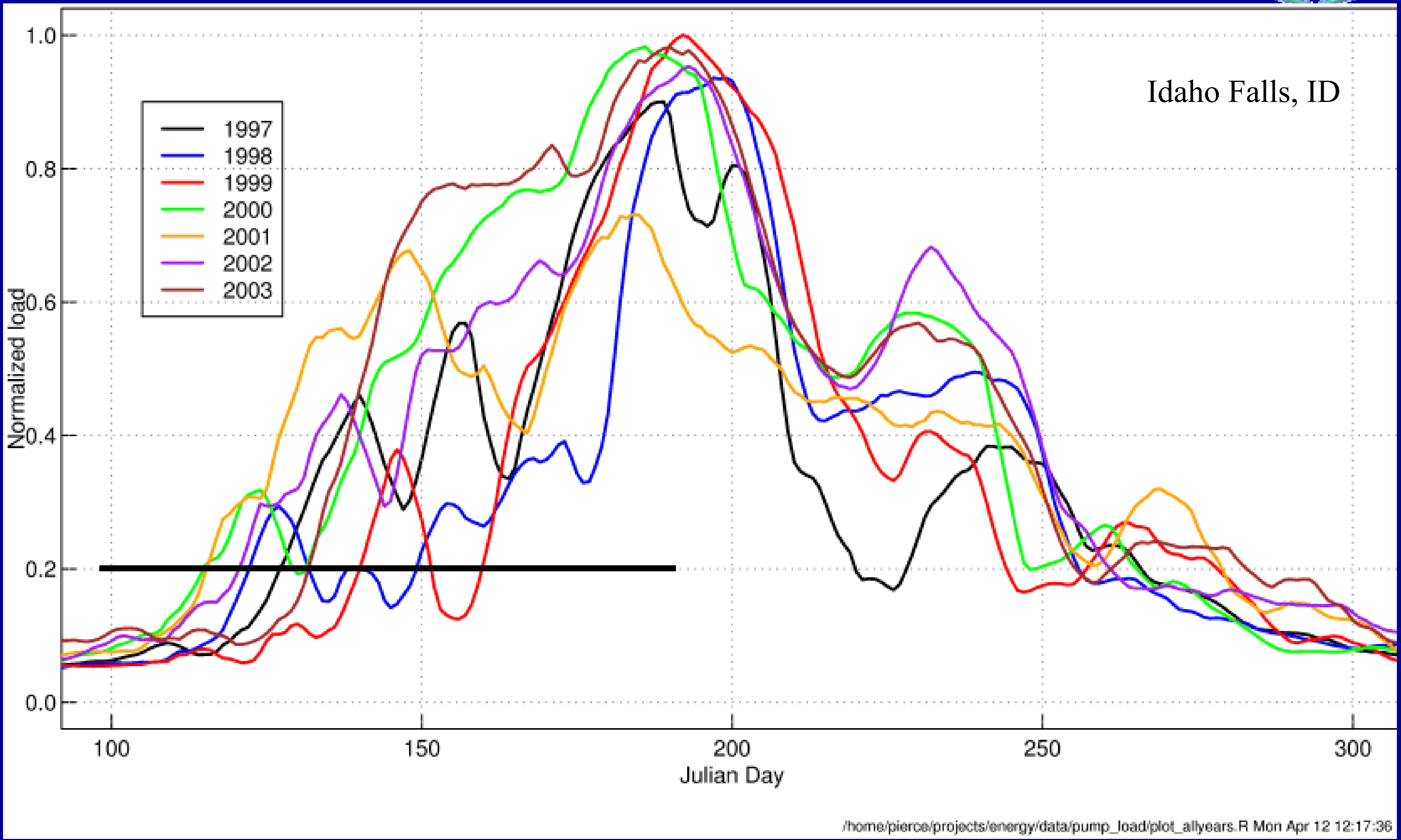
Irrigation pump start date



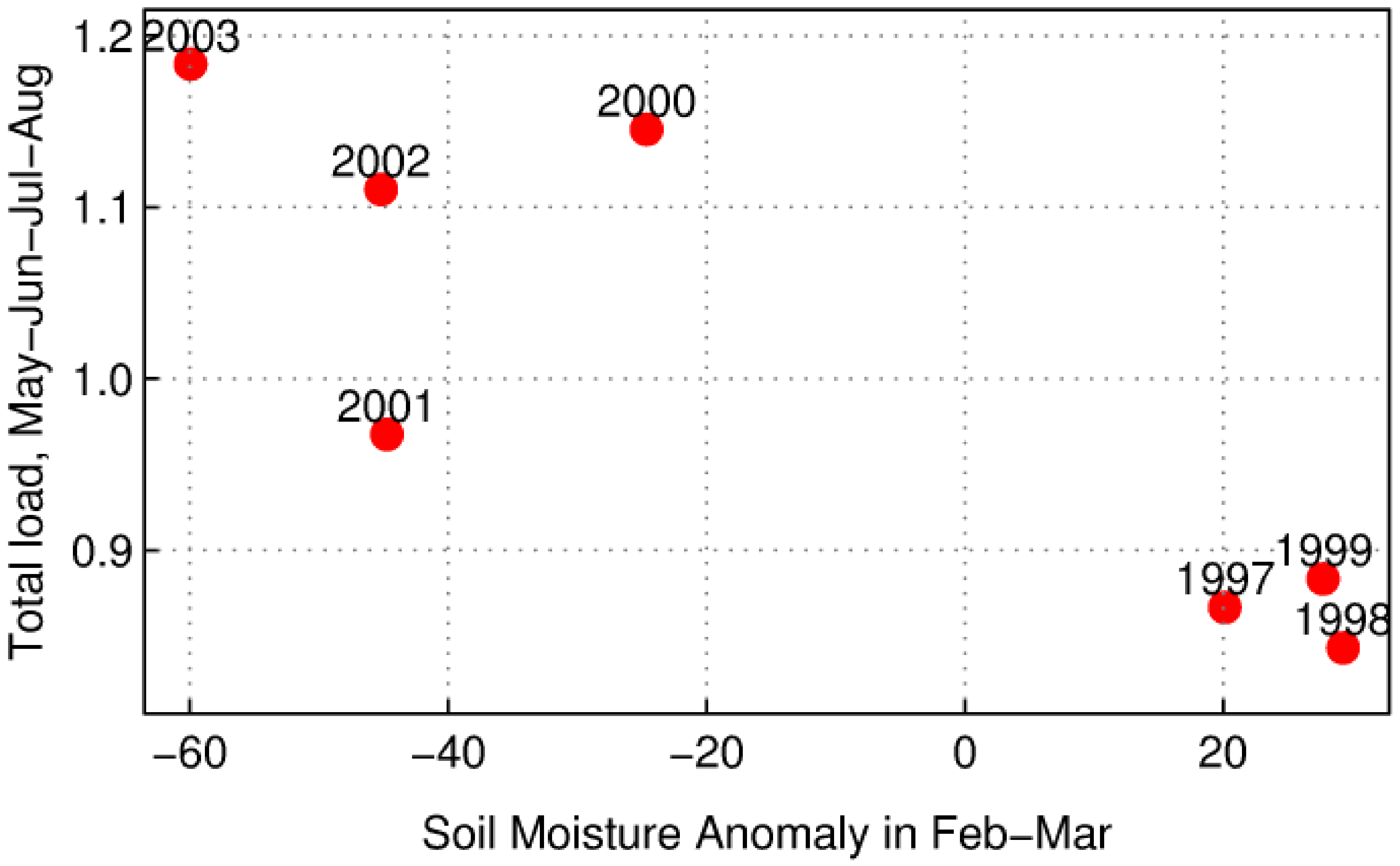
Pump start date

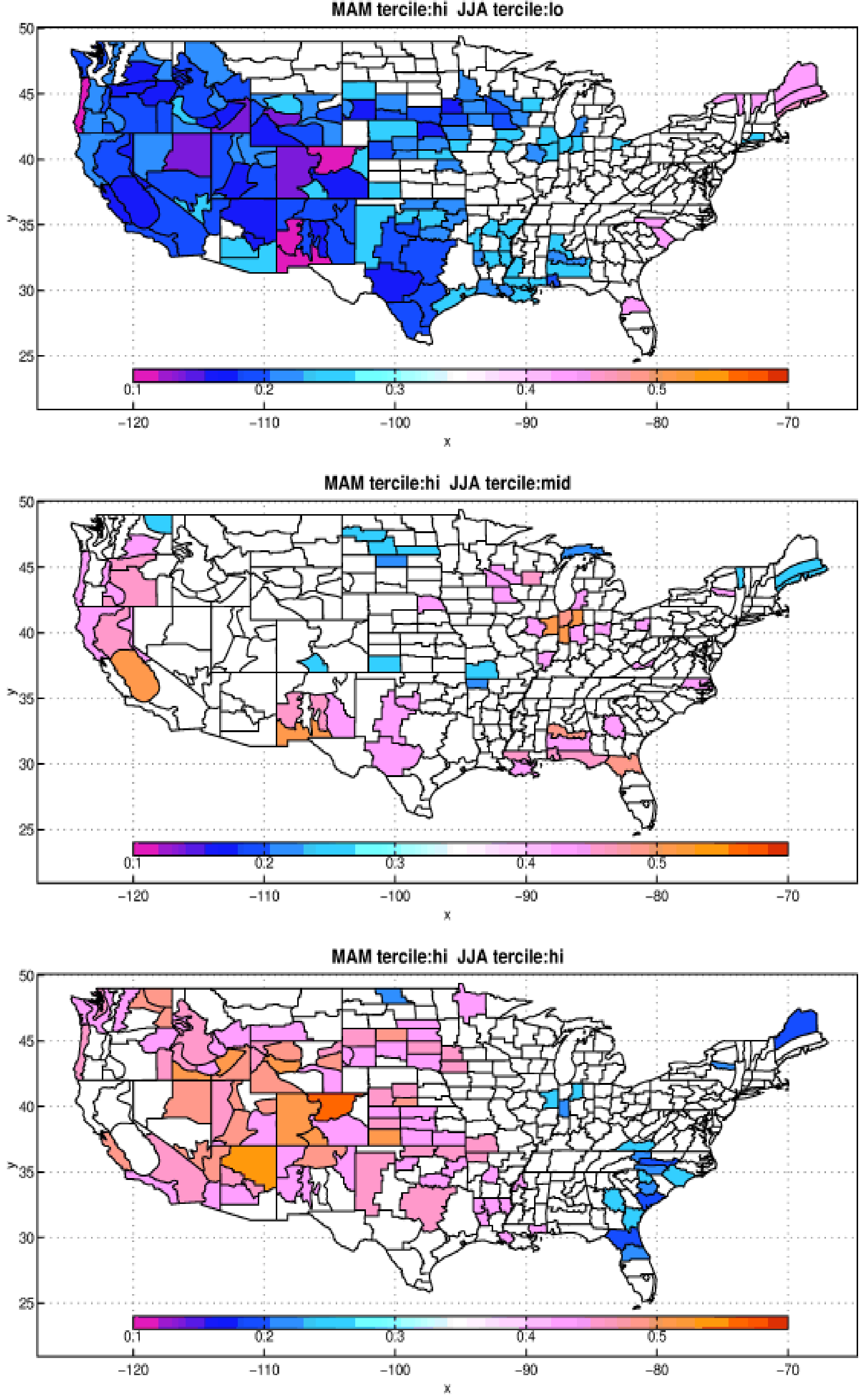


Total use over summer



Total load affected by soil moisture





Predicting summer temperature based on spring temperature

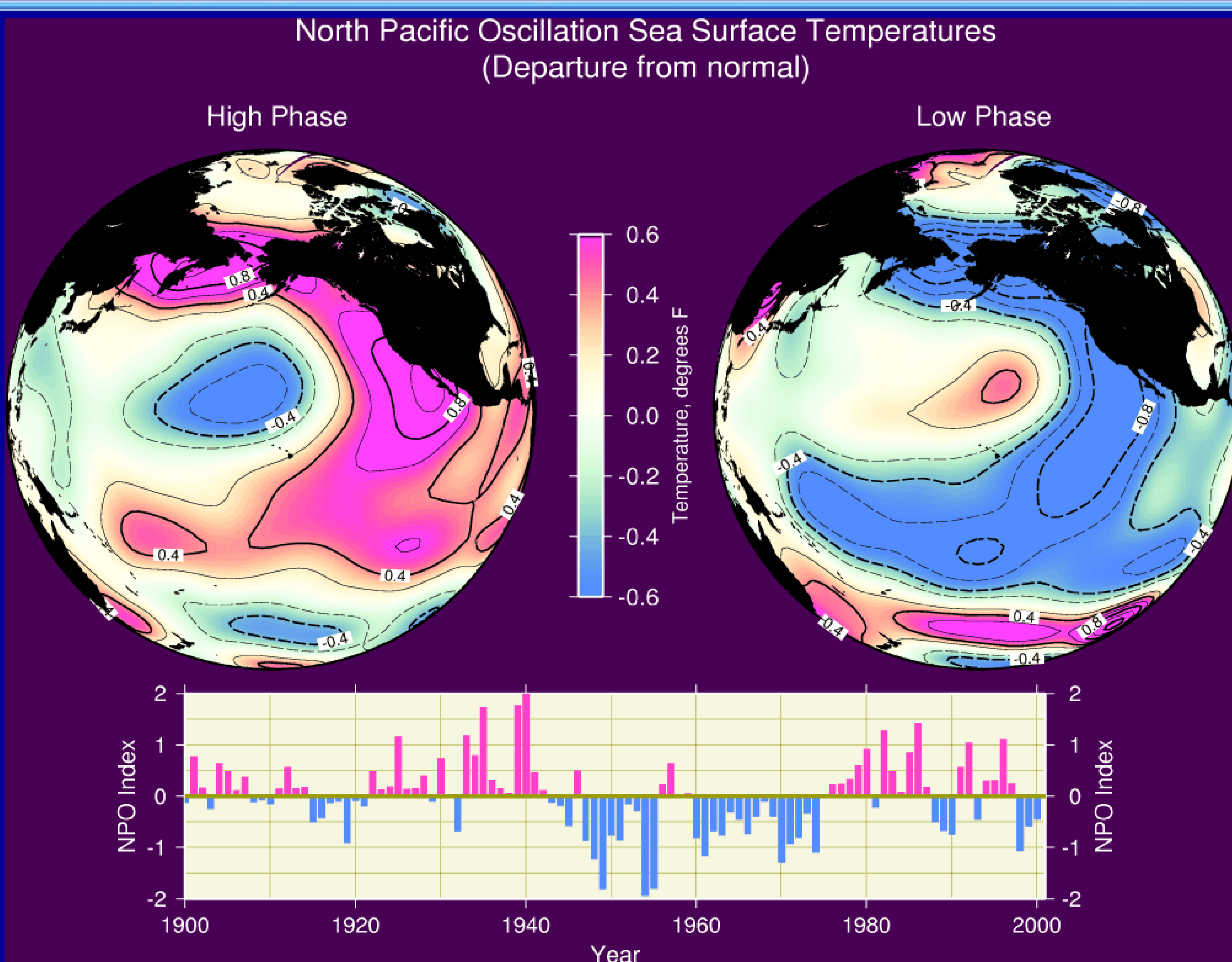
Irrigation load summary

- Buying power contracts 2 months ahead of a high-load summer saves $25/MWh (over spot market price)

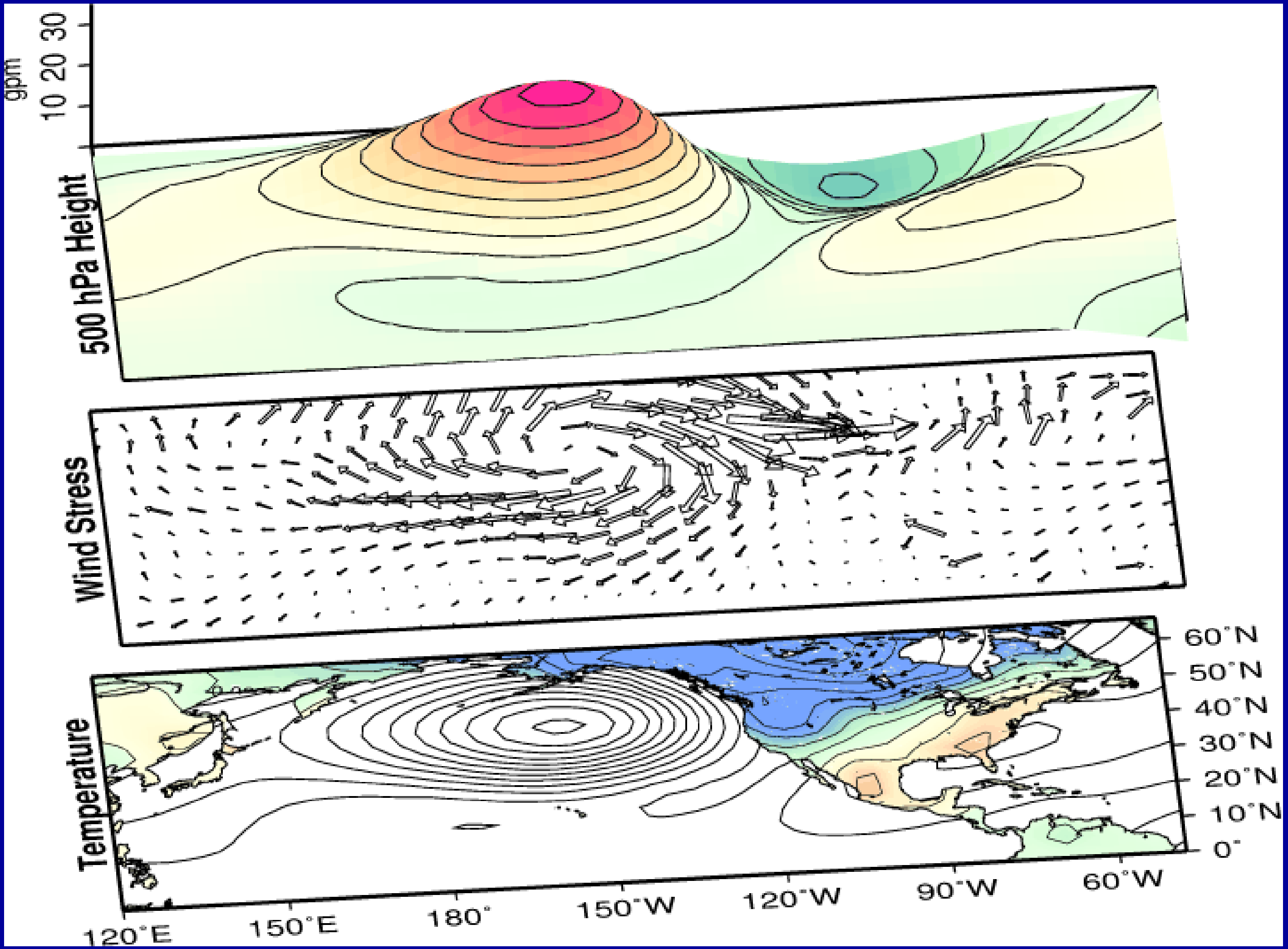
- Use: about 100,000 MWh

- Benefit of 2 month lead time summer load forecast: $2.5 M

4. Pacific Sea Surface Temperatures



Why the NPO matters



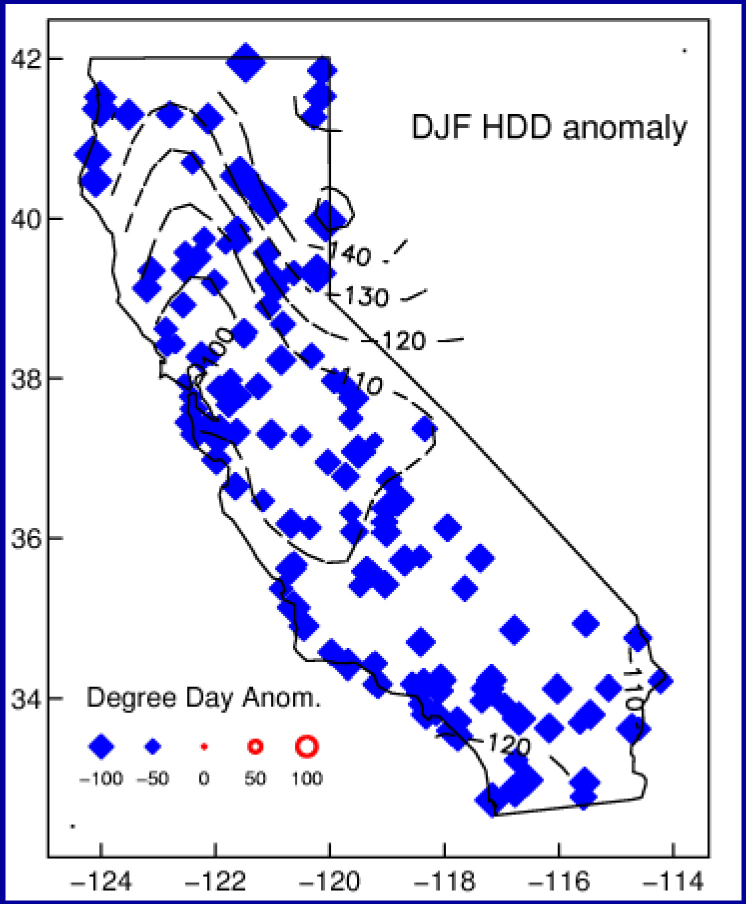
Higher than usual pressure associated with the NPO…

generates anomalous winds from the north west…

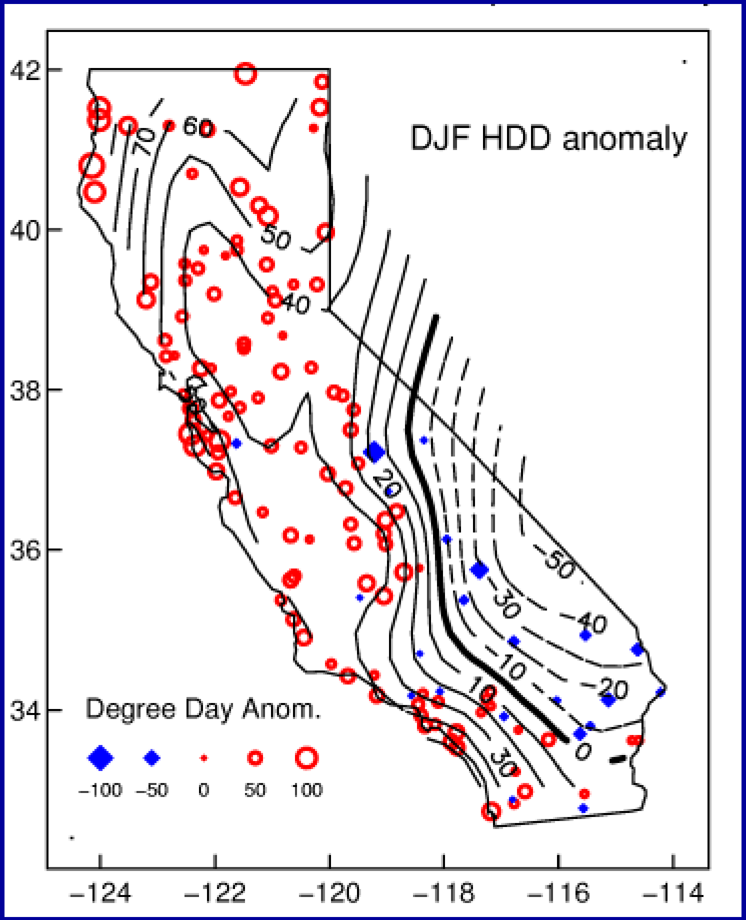
…which bring more cold, arctic air into the western U.S. during winter

NPO and heating degree days

Positive NPO

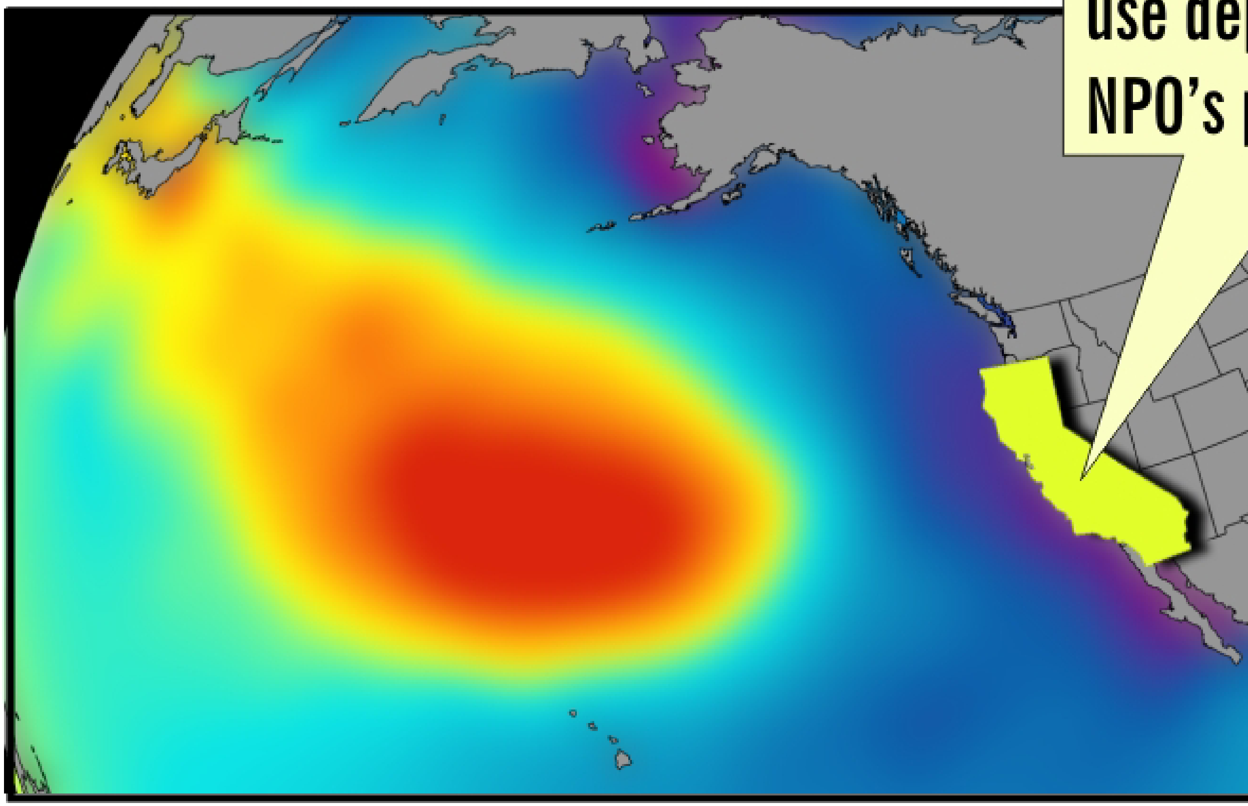


Negative NPO

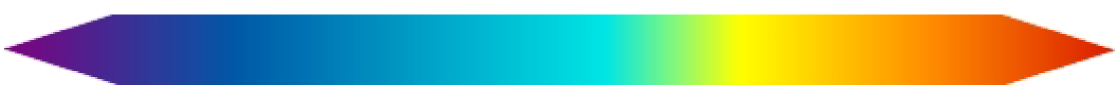


Difference is about 150 HDD, or 5% of total HDD

Ocean Surface Temperature: the North Pacific Oscillation (NPO)



$220M/yr change in California natural gas use depending on the NPO's phase*

Colder  Warmer

Scripps Institution of Oceanography: California energy security project

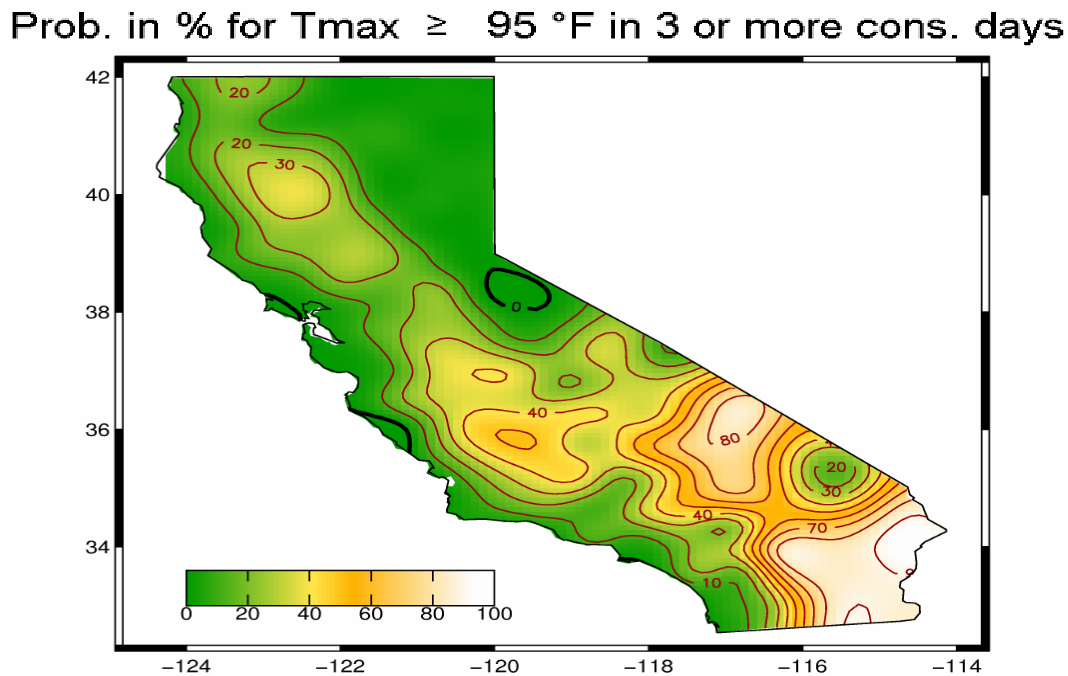
*Natural gas cost estimates from the California Energy Commission; includes residential and commercial gas consumption.

Summer forecast objectives

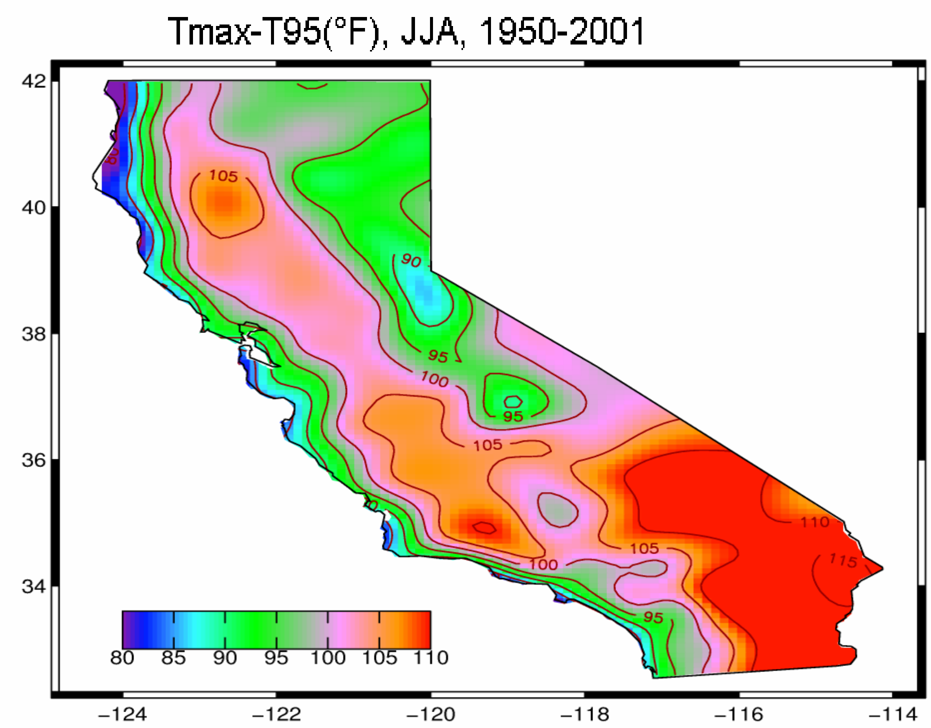
- Develop forecasts of interest to the CEC
- Focus on: extreme events, strings of hot days, CDD
- Technique: use an advanced statistical approach (Canonical Correlation Analysis)

Extreme events

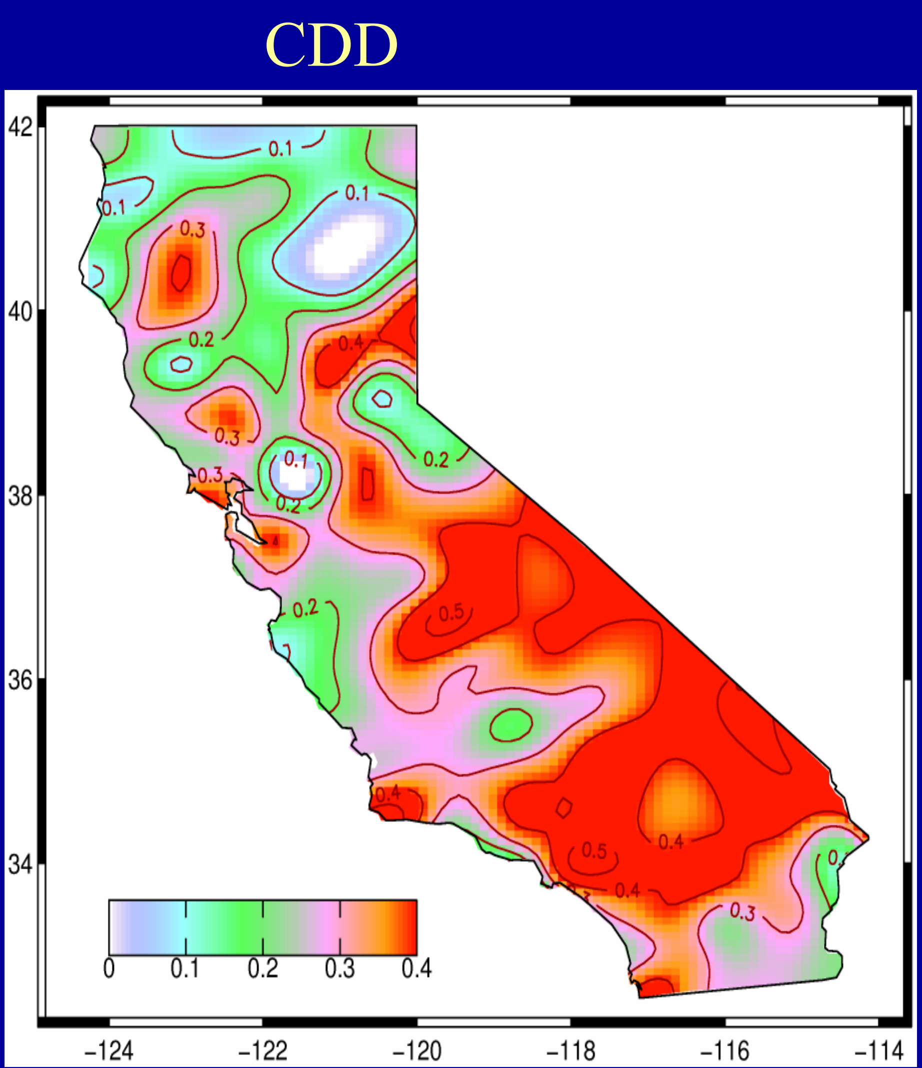
Same *temperature* threshold (e.g. 95 °F) =>

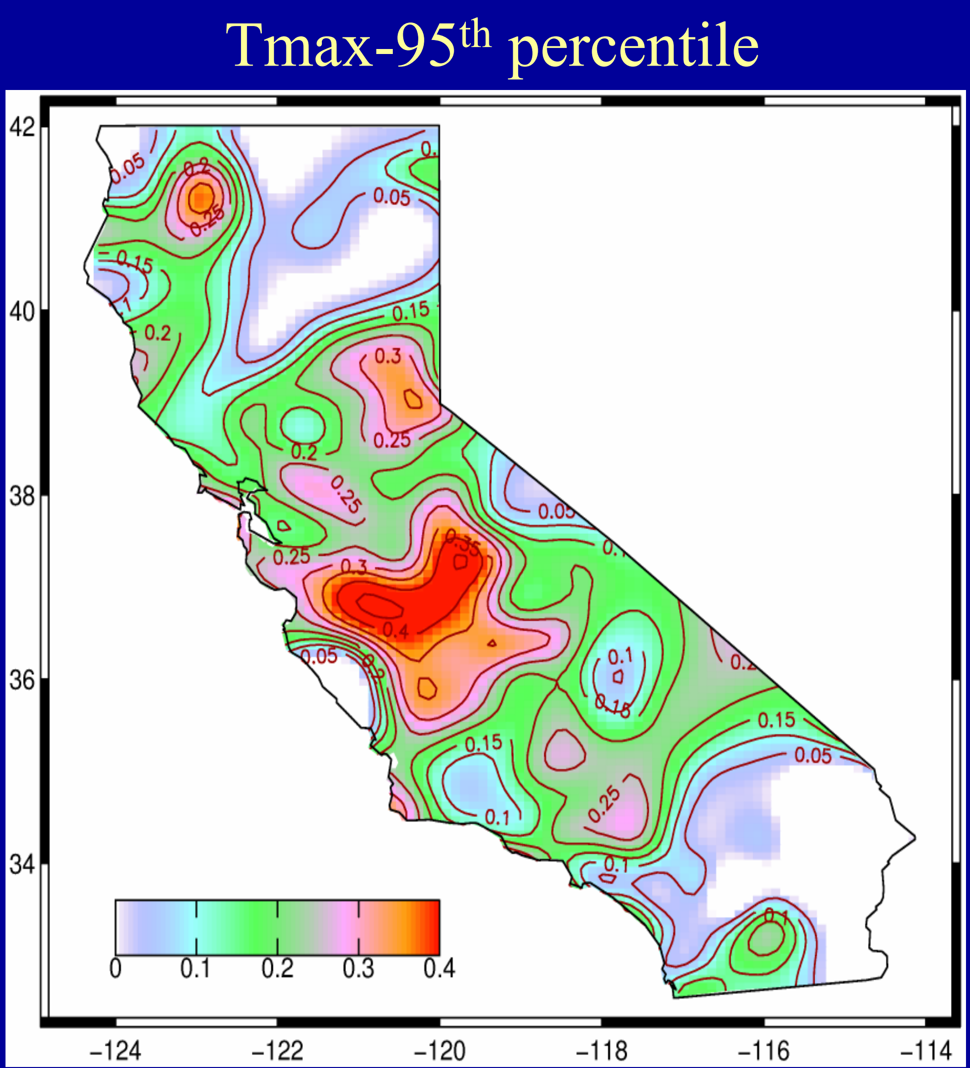


Same *percentile* threshold (e.g. 95th) =>

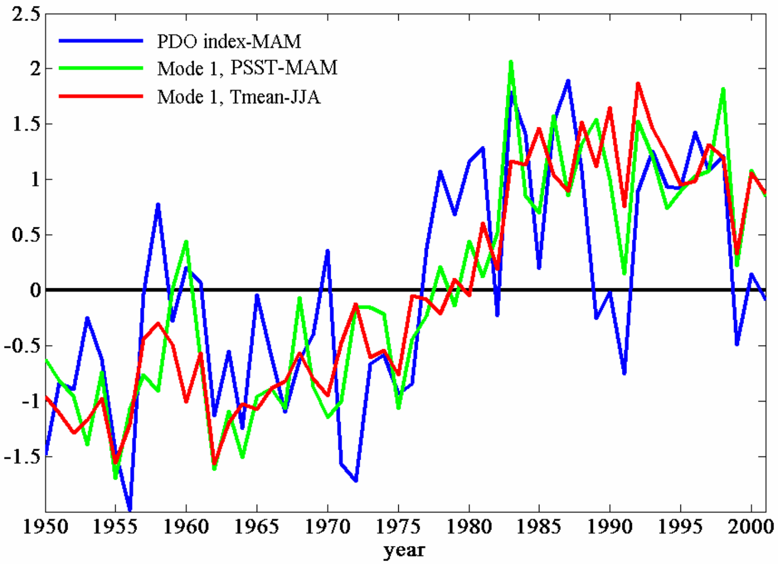


Spring SST predicting summer temperatures

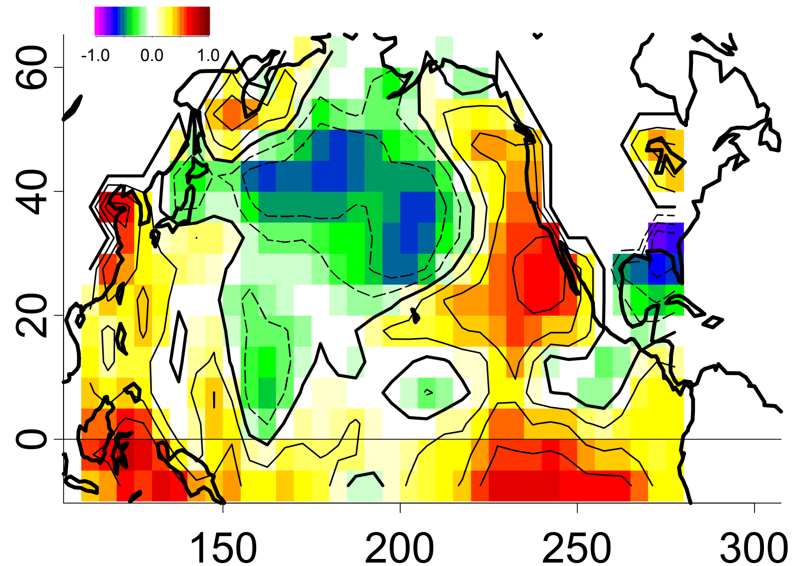




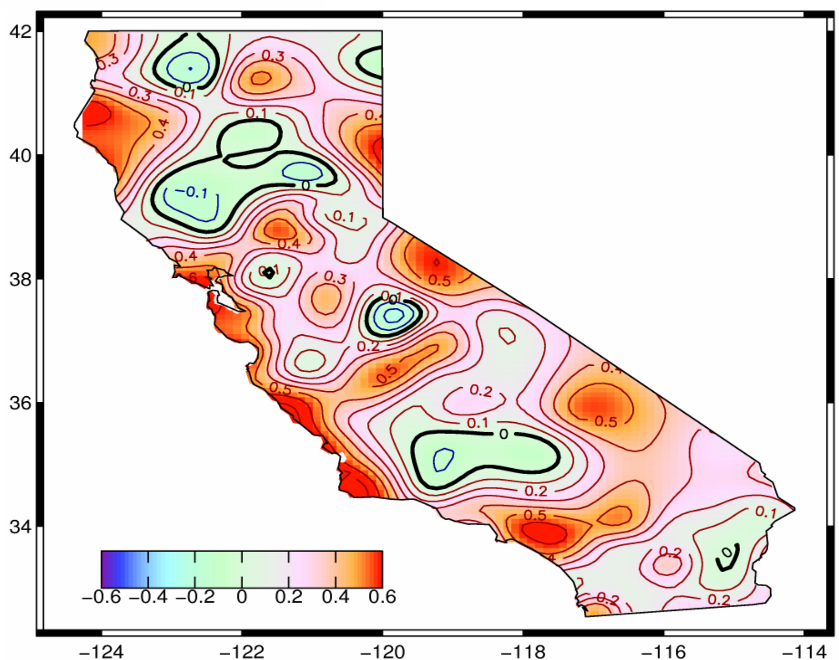
Relationship PDO => California Summertime Temperatures



Correlations, Mode 1-PSST, MAM



Correlations, Mode 1-Tmean, JJA =>



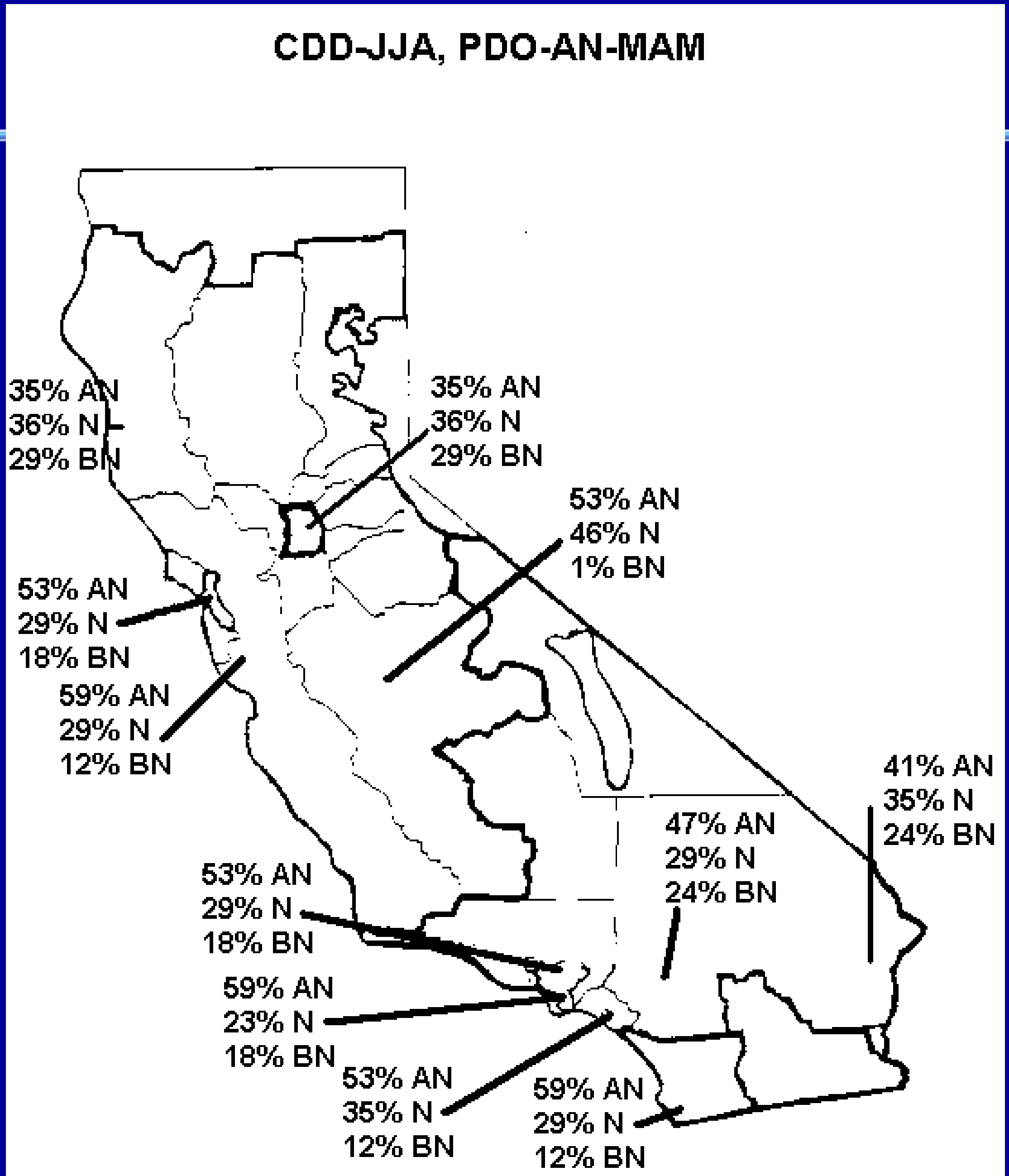
Contingency Analysis (conditional probabilities):

Burbank-Glendale-Pasadena		< 736	**CDD-JJA**	> 856
		BN	N	AN
PDO	BN	53**	29	18*
MAM	N	29	42	29
	AN	18*	29	53**

San Jose		< 331	**CDD-JJA**	> 414
		BN	N	AN
PDO	BN	53**	35	12***
MAM	N	35	36	29
	AN	12***	29	59***

α = 0.01 => ***, 0.05 => **, 0.10 => *

Summer CDD when PDO above normal in spring



Pacific SST & CA temperatures summary

- Spring Pacific sea surface temperatures predict summer temperature in California
- Above normal PDO is associated with warm CA summers (and below normal PDO with cold summers)
- Possible uses of this information include risk reduction, and improved planning and reliability

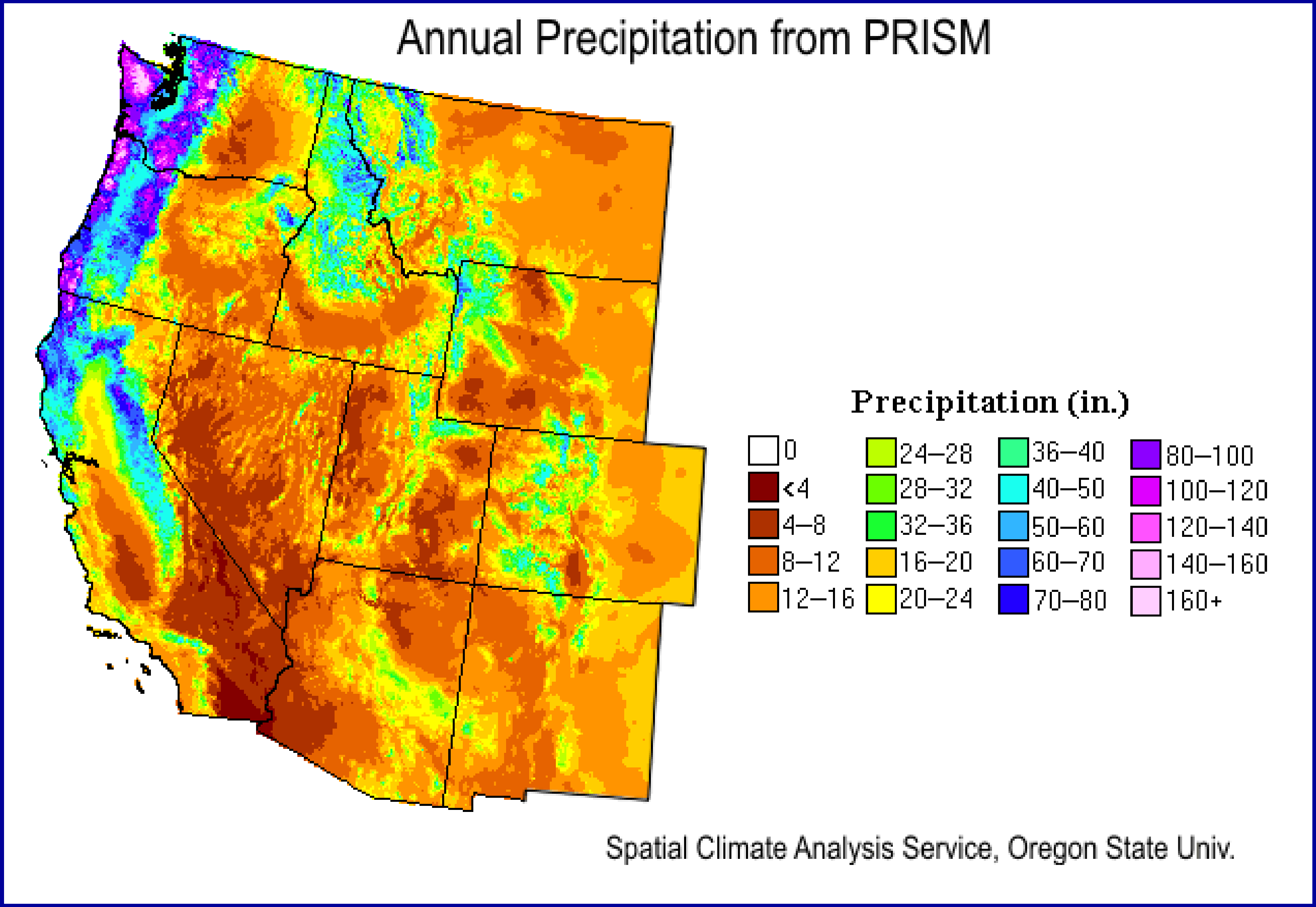
5. Precipitation, Runoff, and Hydropower

- Work done by U.W. hydrology group (Dennis Lettenmaier, Alan Hamlet, Nathalie Voisin)
- How much does hydropower production vary given realistic climate fluctuations?
- What are the regional implications?

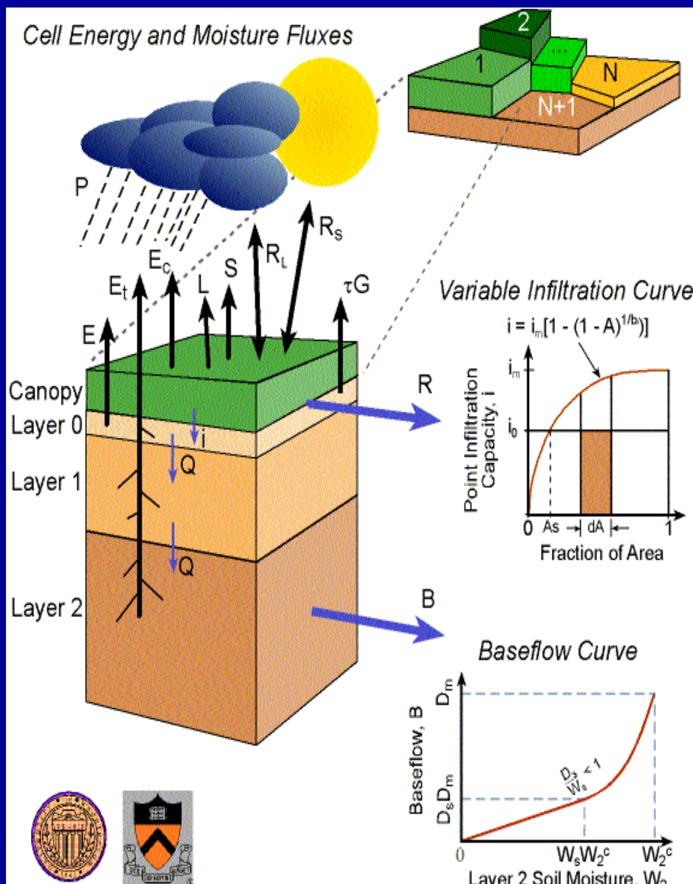
Step 1: Develop climate forcing fields

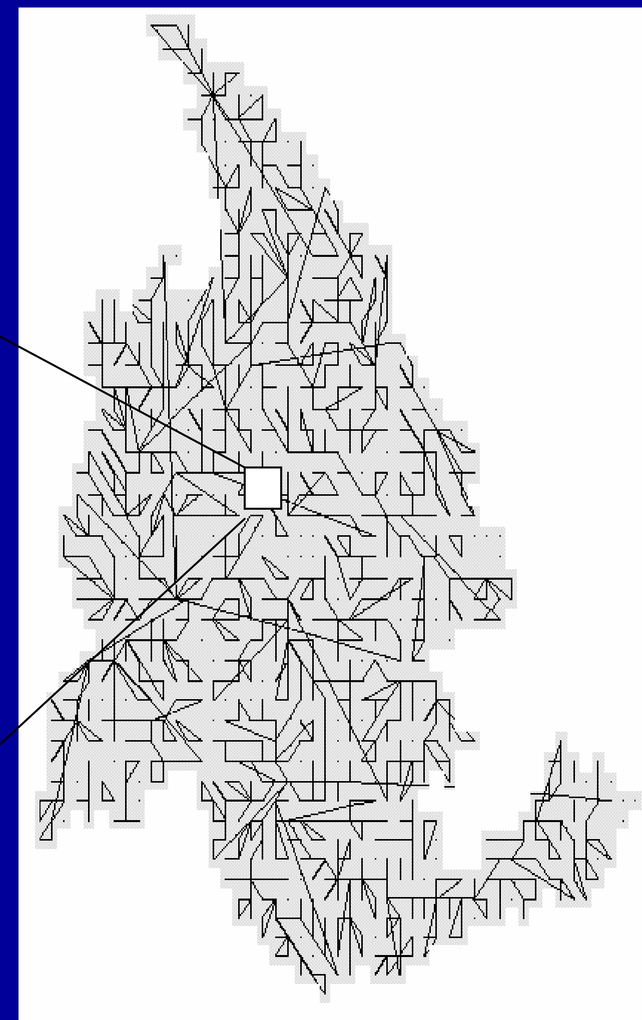
- Raw station data is biased because stations mostly at low altitude, but streamflow influenced by high-altitude precipitation
- Can correct for altitude effects
- Period: 1916-2002

Step 1: Develop climate forcing fields

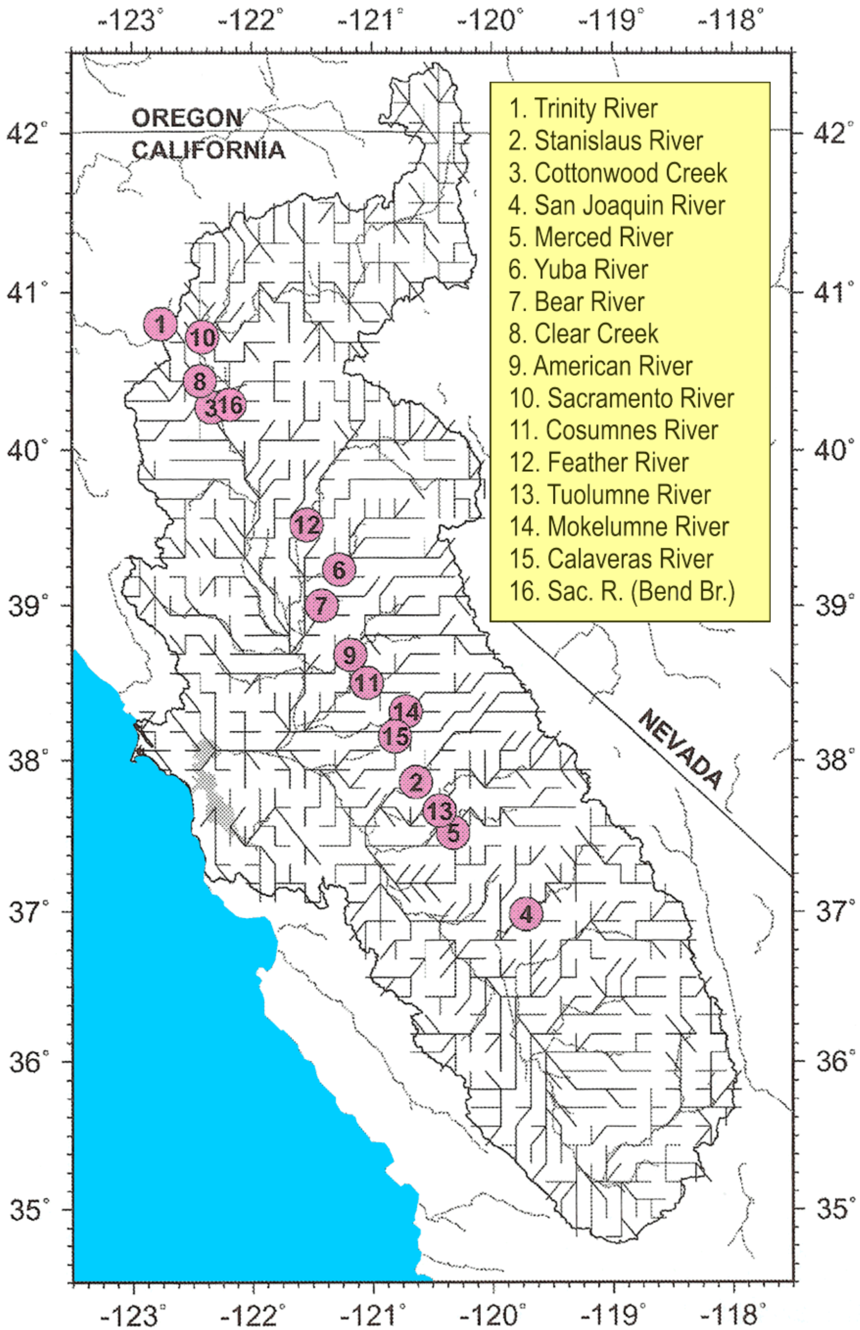


Step 2: Apply to soil/streamflow model



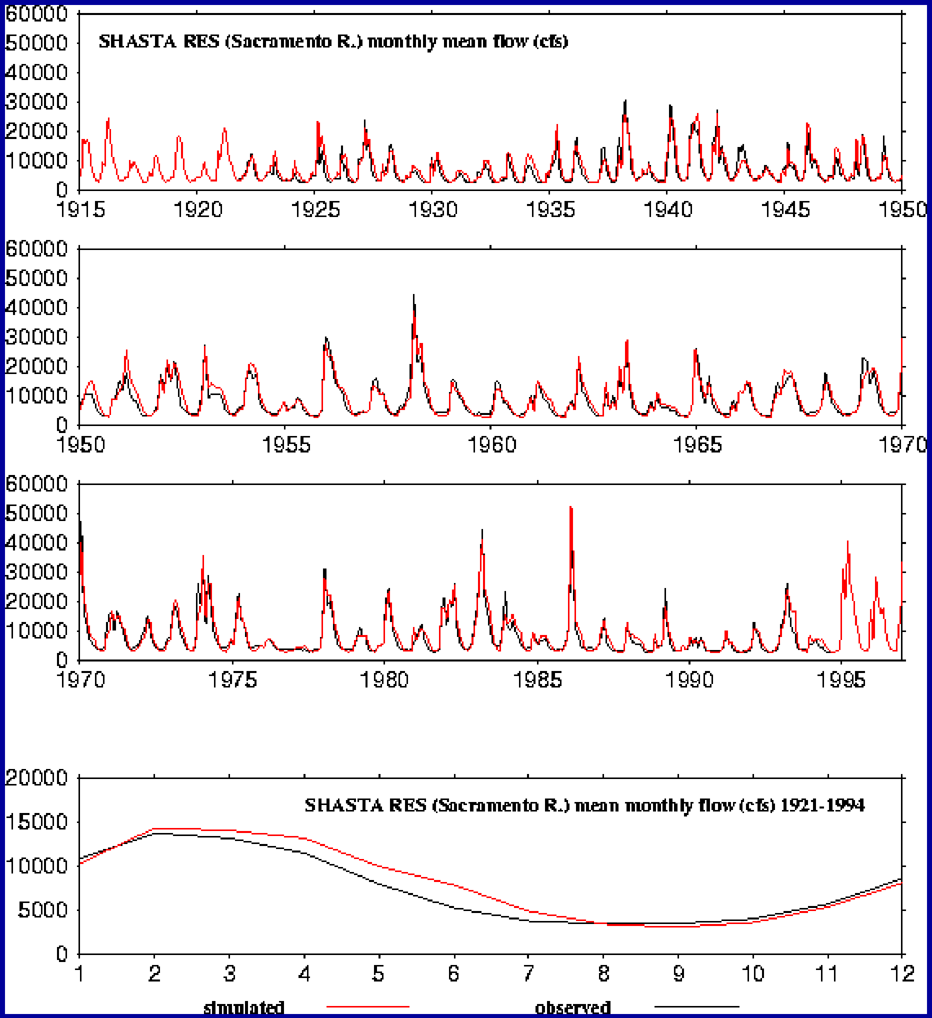


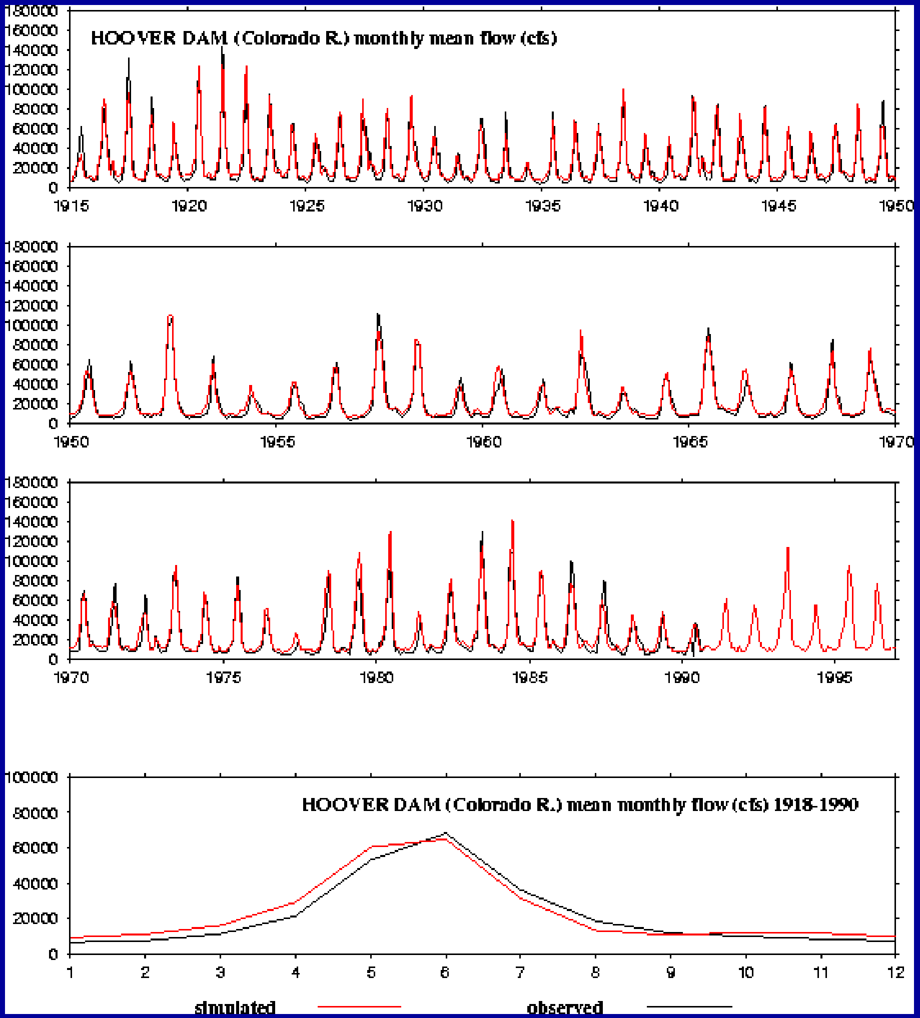
Nathalie Voisin et al., Univ. Washington, 2004



Van Rheenen et al., *Climatic Change*, 2004

Step 3. Verify streamflow





Nathalie Voisin et al., Univ. Washington, 2004

Step 4. Apply to reservoir model

- ColSim (<u>Col</u>umbia <u>Sim</u>ulation) for the Pacific Northwest
- CVmod (<u>C</u>entral <u>V</u>alley <u>mod</u>el) for Sacramento-San Joaquin basin
- Use realistic operating rules:
  - Energy content curves (ECC) for allocating hydropower
  - US Army Corp of Engineers rule curves for flood prevention
  - Flow for fish habitat under Biological Opinion Operating Plan
  - Agricultural withdrawal estimated from observations
  - Recreational use of Grand Coulee Dam reservoir

Major components of CVmod

Lake Shasta	Flood control, navigation, fish conservation	USBR
Lake Trinity	Water supply, hydropower, fish conservation	USBR
Whiskeytown Reservoir	Flood control, hydropower	USBR
Lake Oroville	Flood control, water supply, hydropower, water quality, environmental conservation	DWR
Folsom Lake	Flood control, water supply, hydropower	USBR
Pardee/Camanche Resv.	Flood control, water supply	EBMUD
New Hogan Reservoir	Flood control, water supply	COE
New Melones Reservoir	Flood control, water supply, water quality, hydropower	USBR
New Don Pedro Res./Lake McClure	Flood control, water supply	TMID, MC
Millerton/Eastman/Hensley	Water supply, recreation	USBR, COE
Sacramento-San Joaquin Delta	Water supply, water quality	USBR, DWR
San Luis Reservoir	Water supply, hydropower	USBR, DWR

USBR:
Bureau of Reclamation

DWR:
CA Dept Water Resources

EBMUD:
East Bay Municipal District

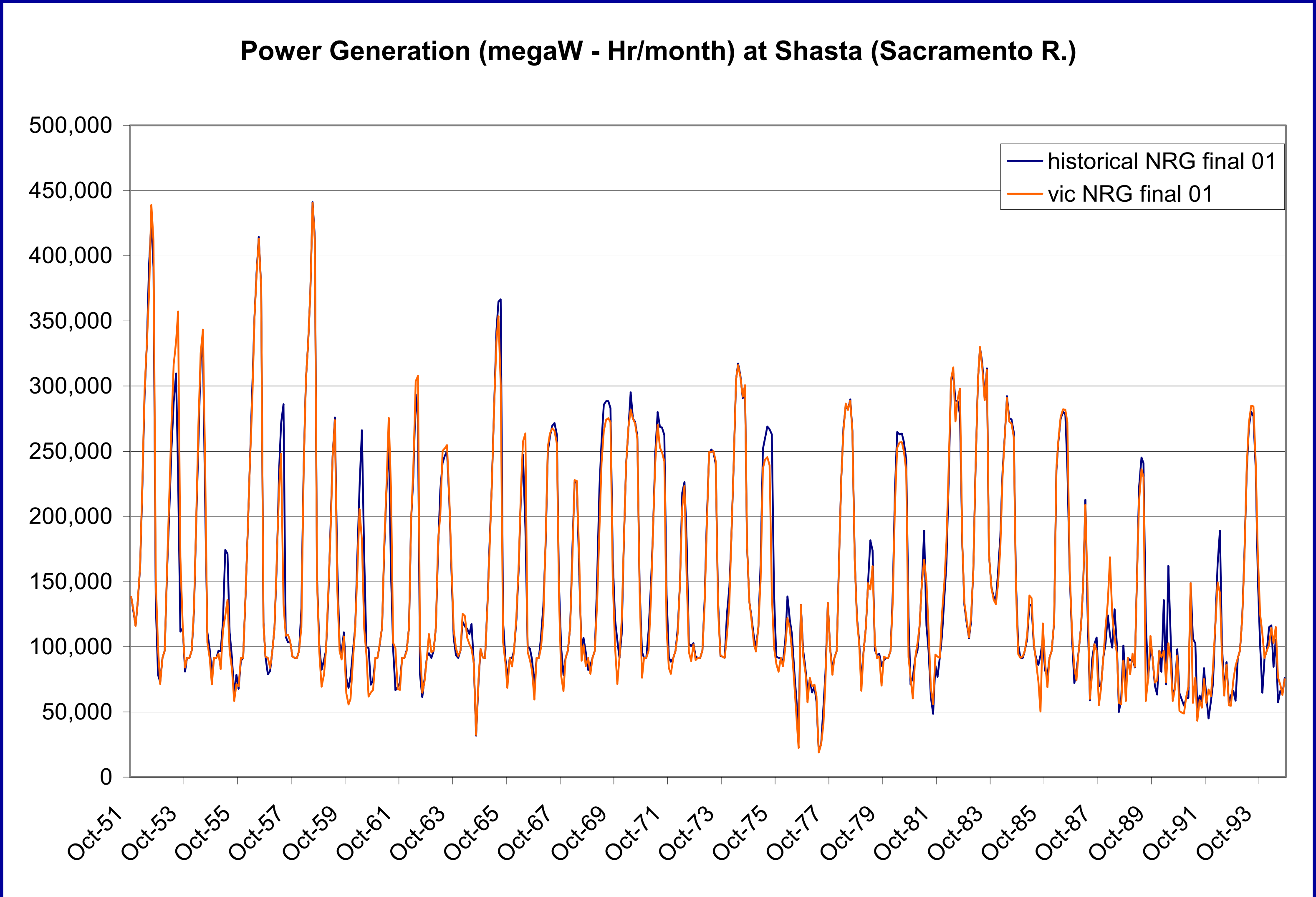
MC:
Merced County

TID:
Turlock Irrigation District

COE:
US Army Corp of Engineers

Van Rheenen et al., Climatic Change, 2004

Step 5. Hydropower production



N. Voisin et al., Univ. Wash., 2004

Hydropower summary

- Strong climate-related year to year variability in CA hydropower
- Working on forecasting that variability using same techniques that worked for summer temperatures
- Possible benefits of such forecasts include better water/hydropower management and reduced costs

Case studies: summary

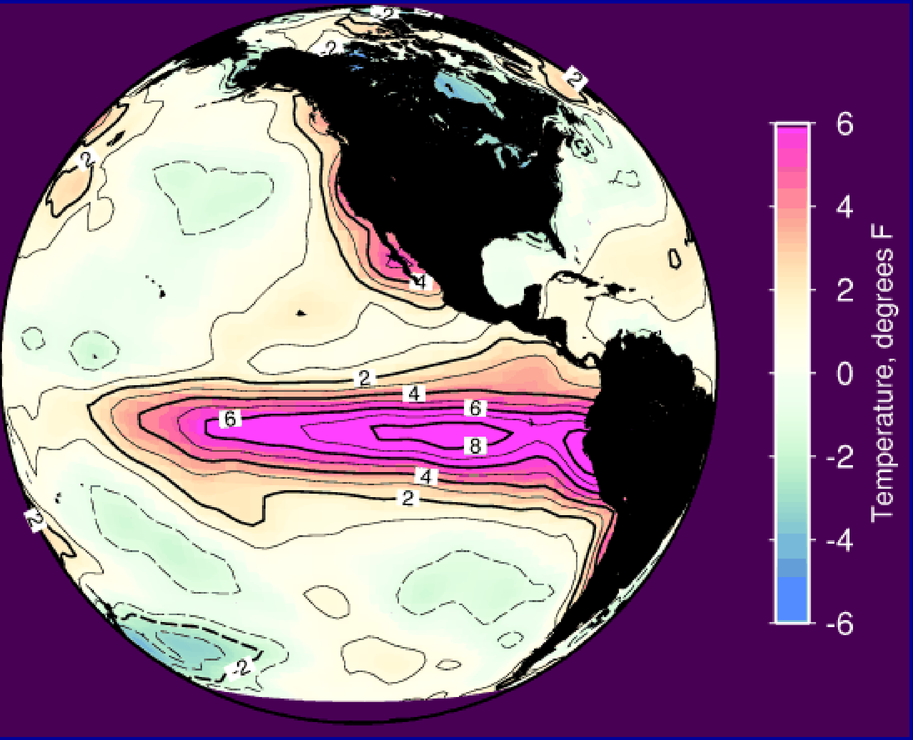
What is the economic value of climate forecasts to the energy sector?

1. Improved bay area and delta breeze forecasts: $100K's to low $millions/yr
2. Peak day load management: ~$1-10M/yr
3. Pump loads: ~$2M/yr
4. Pacific SSTs: benefits of the information might include risk reduction, improved reliability, and improved planning
5. Hydropower: better water management, reduced costs

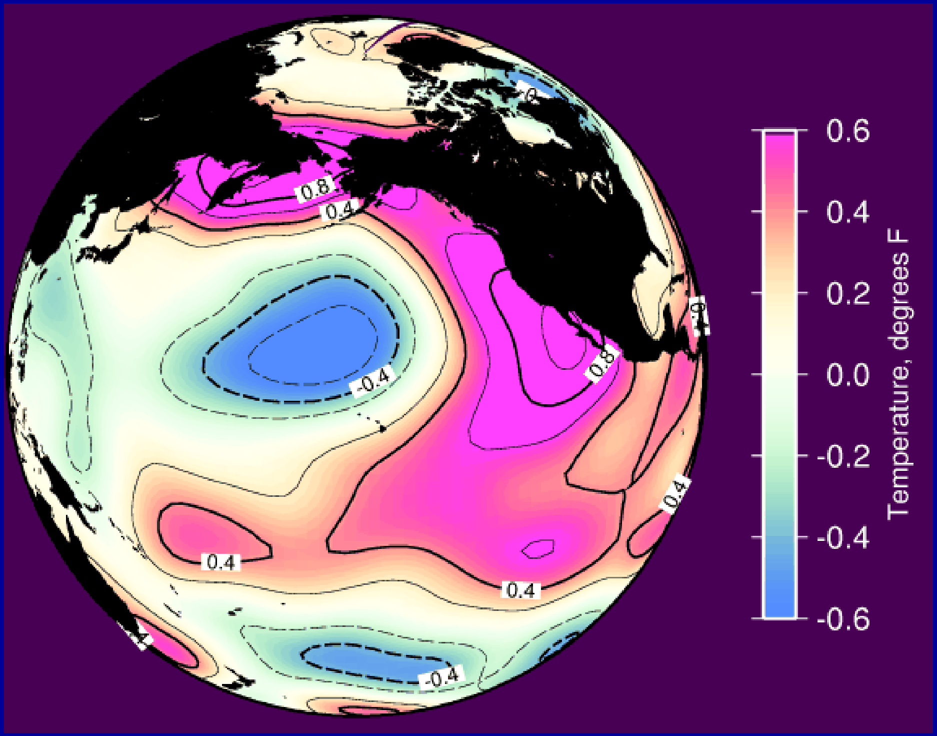
Where we could go from here…

Climate variations…

El Nino



North Pacific Oscillation (NPO)



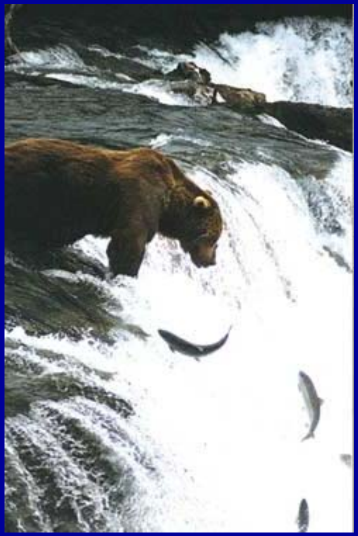
…affect energy…

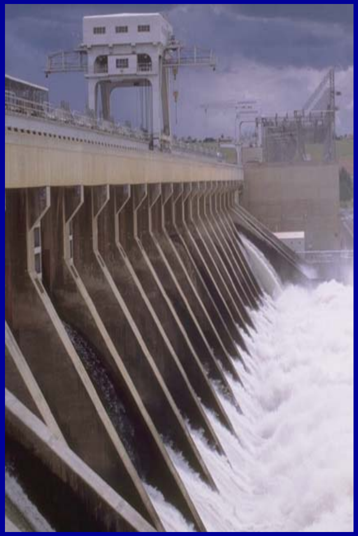
supply

demand

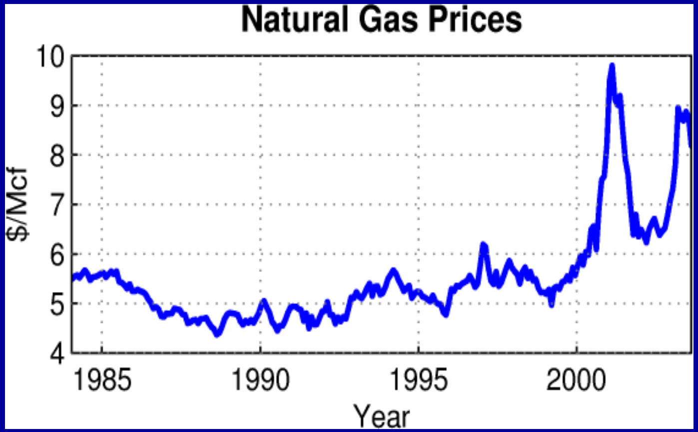
…and therefore *decisions*.

Environment vs. Hydropower



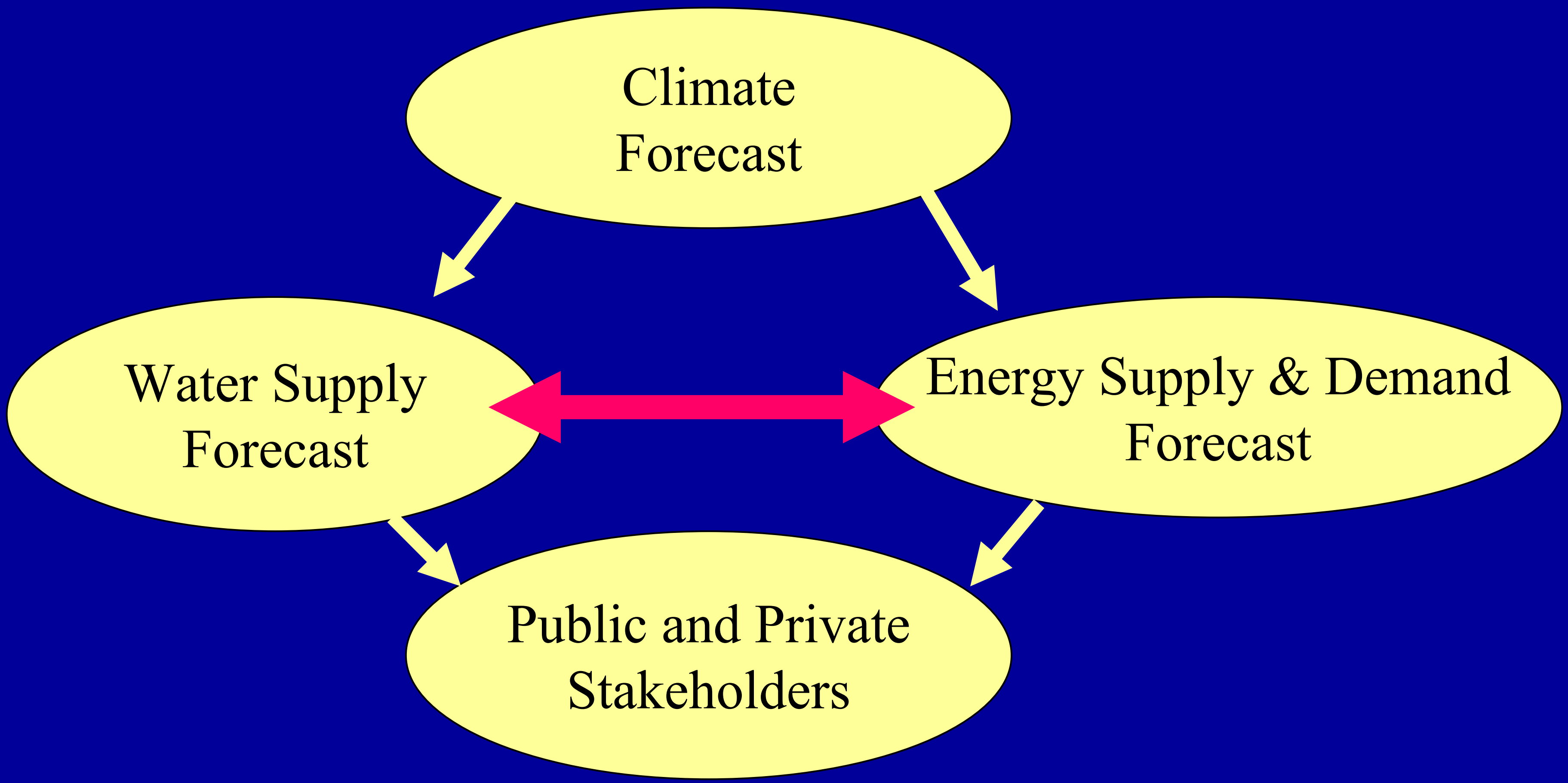


Urban vs. Agriculture



Long term contracts
vs.
Spot market

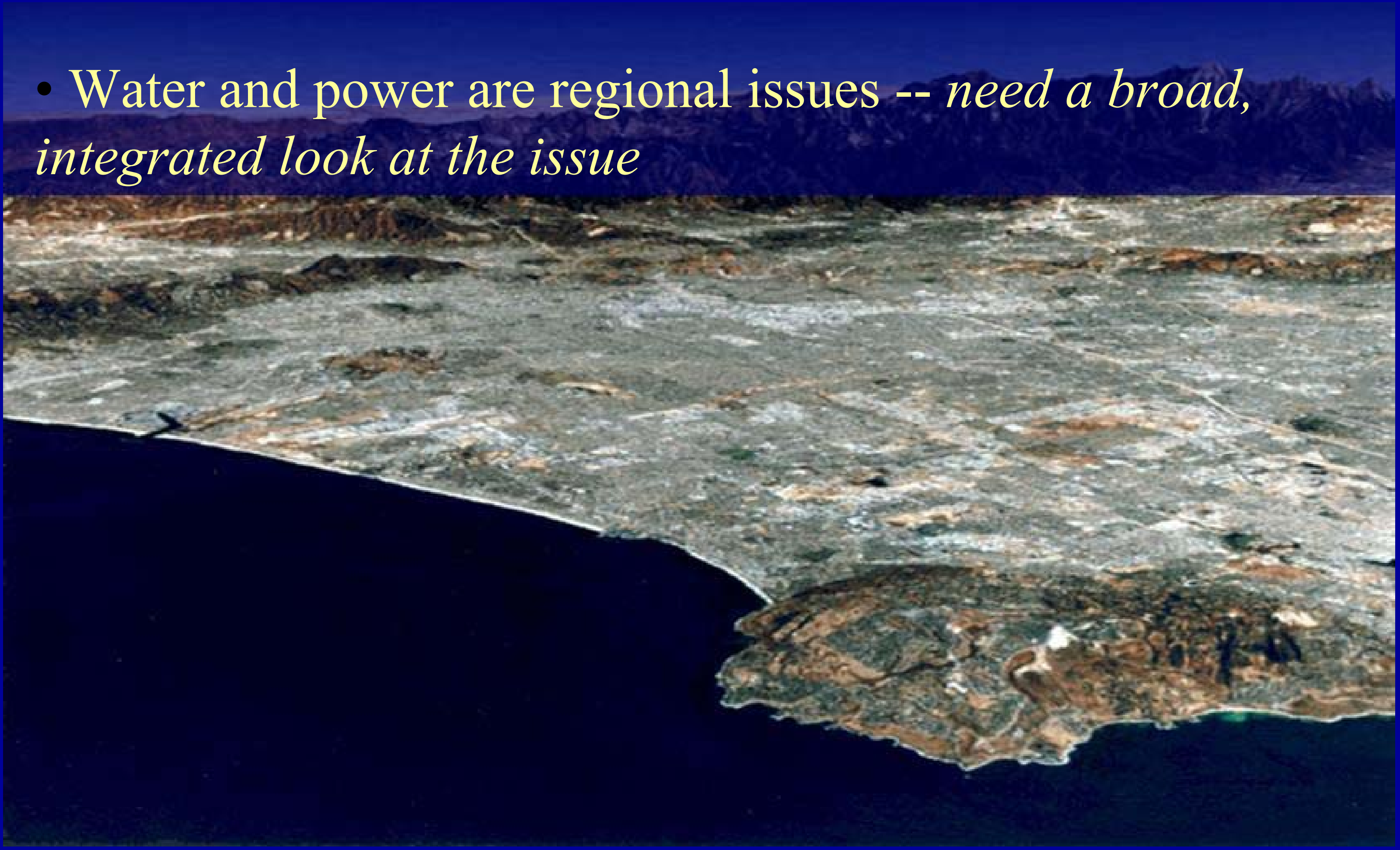
Water-Energy interaction



An Energy-Water Opportunity

An Energy-Water Opportunity

- Water and power are regional issues -- *need a broad, integrated look at the issue*



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- The pieces to do this problem are already there -- *but no one has brought them all together yet*
- *A project whose time has come*

SCRIPPS

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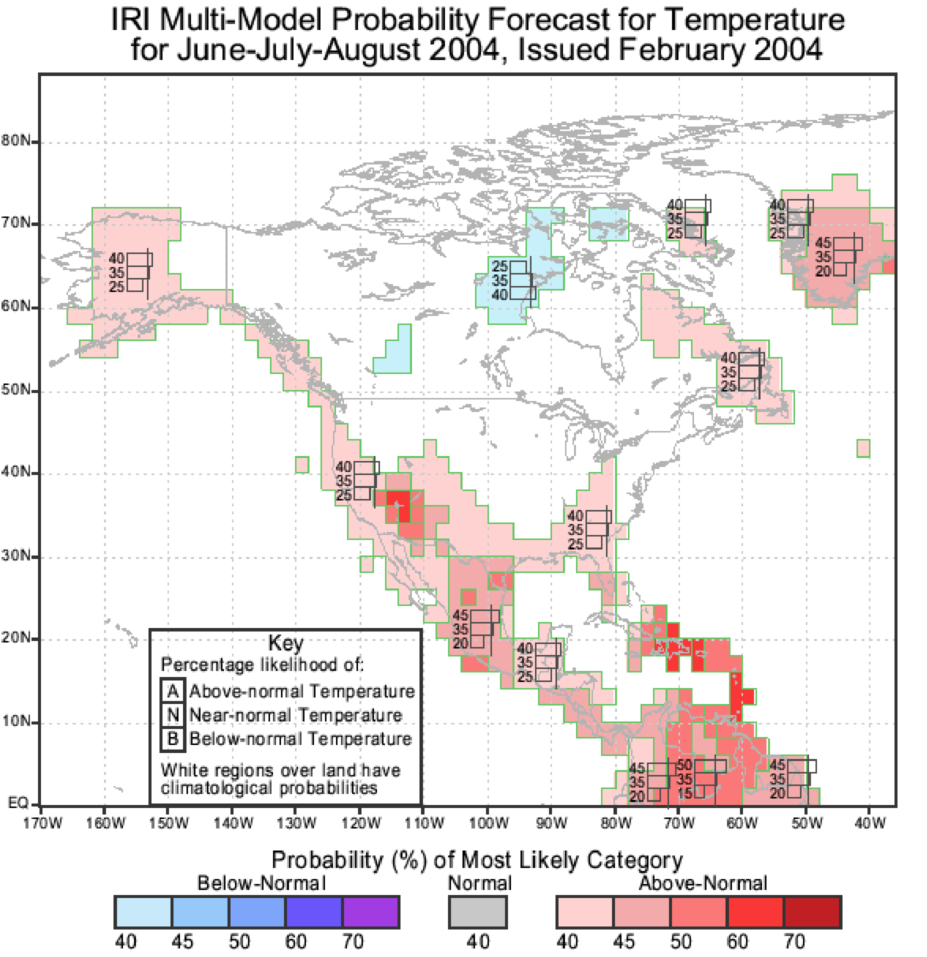
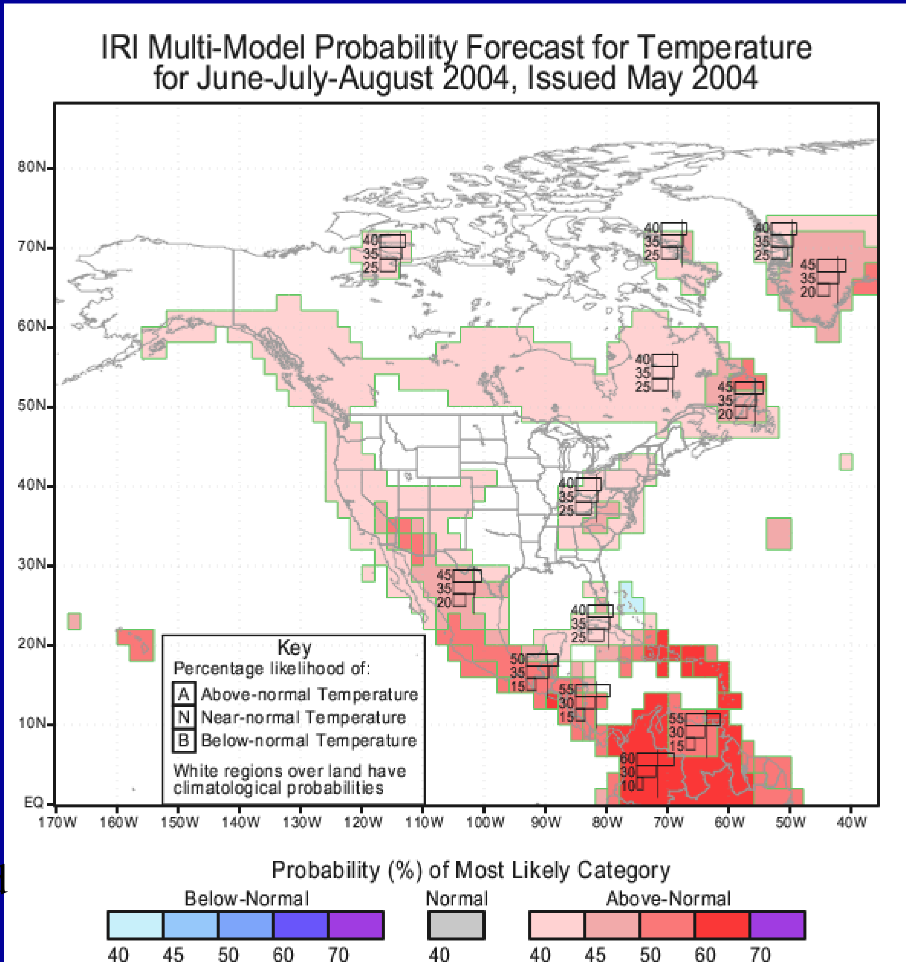
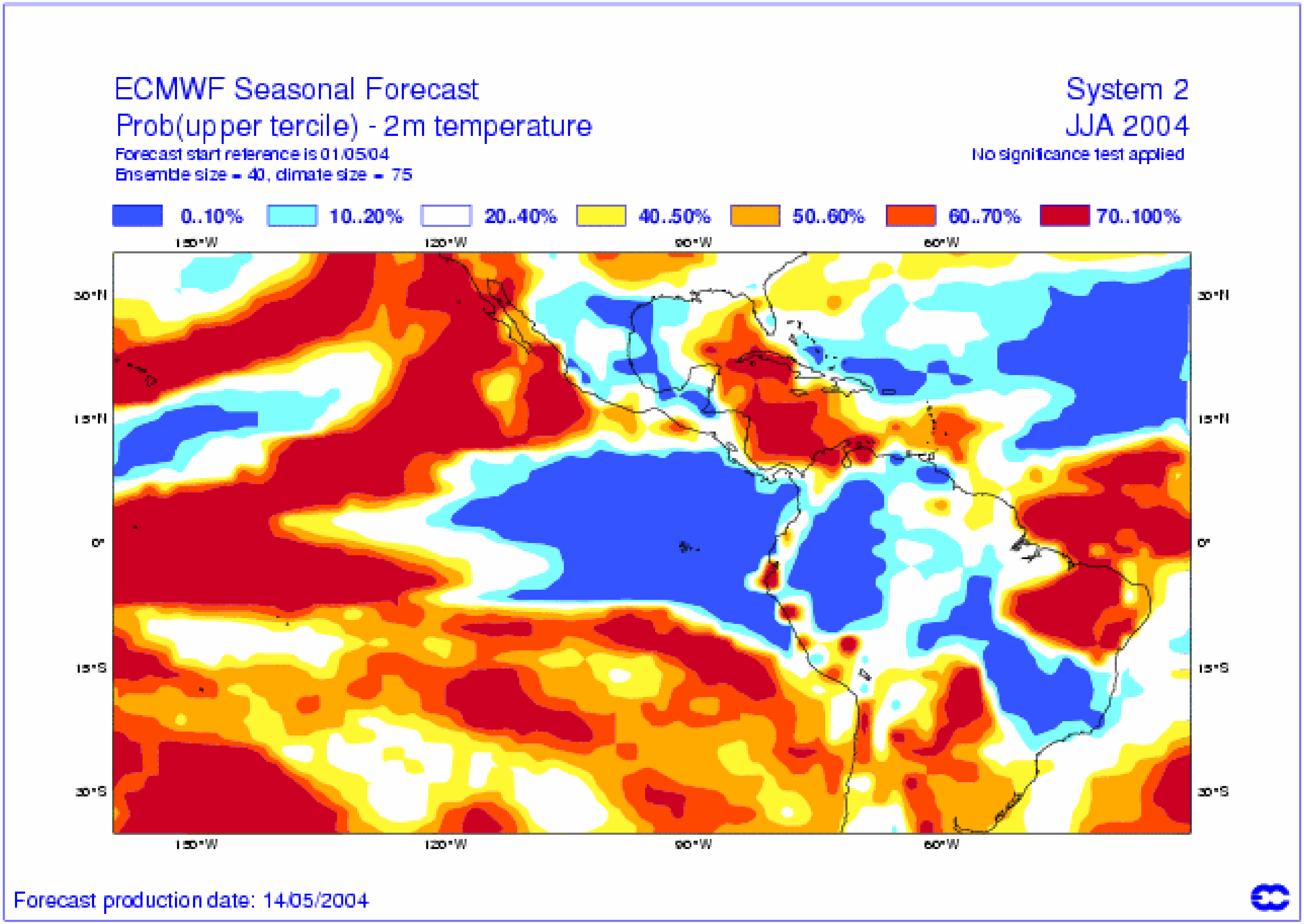
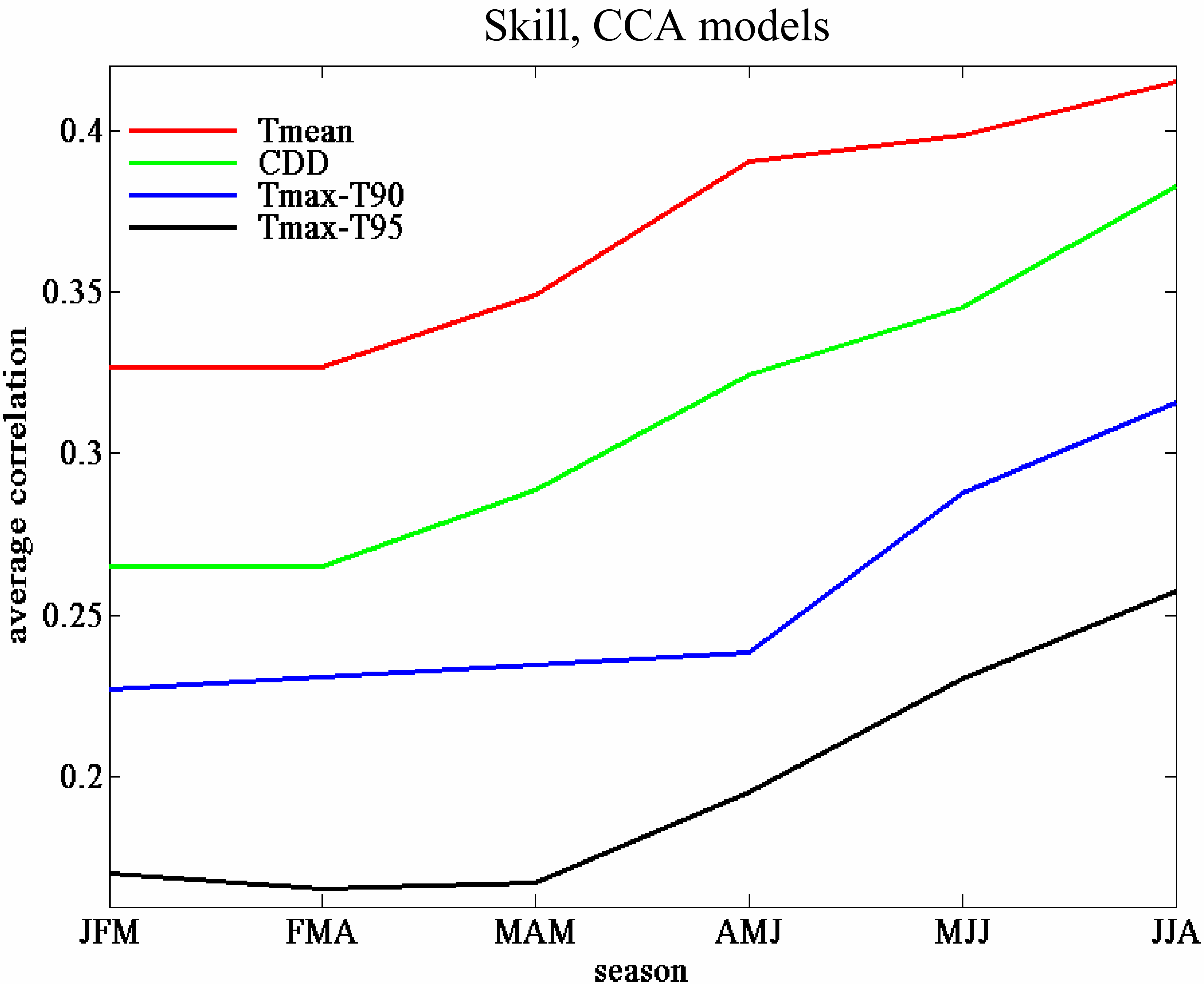




http://iri.columbia.edu/climate/forecast/net_asmt/2004/index.html

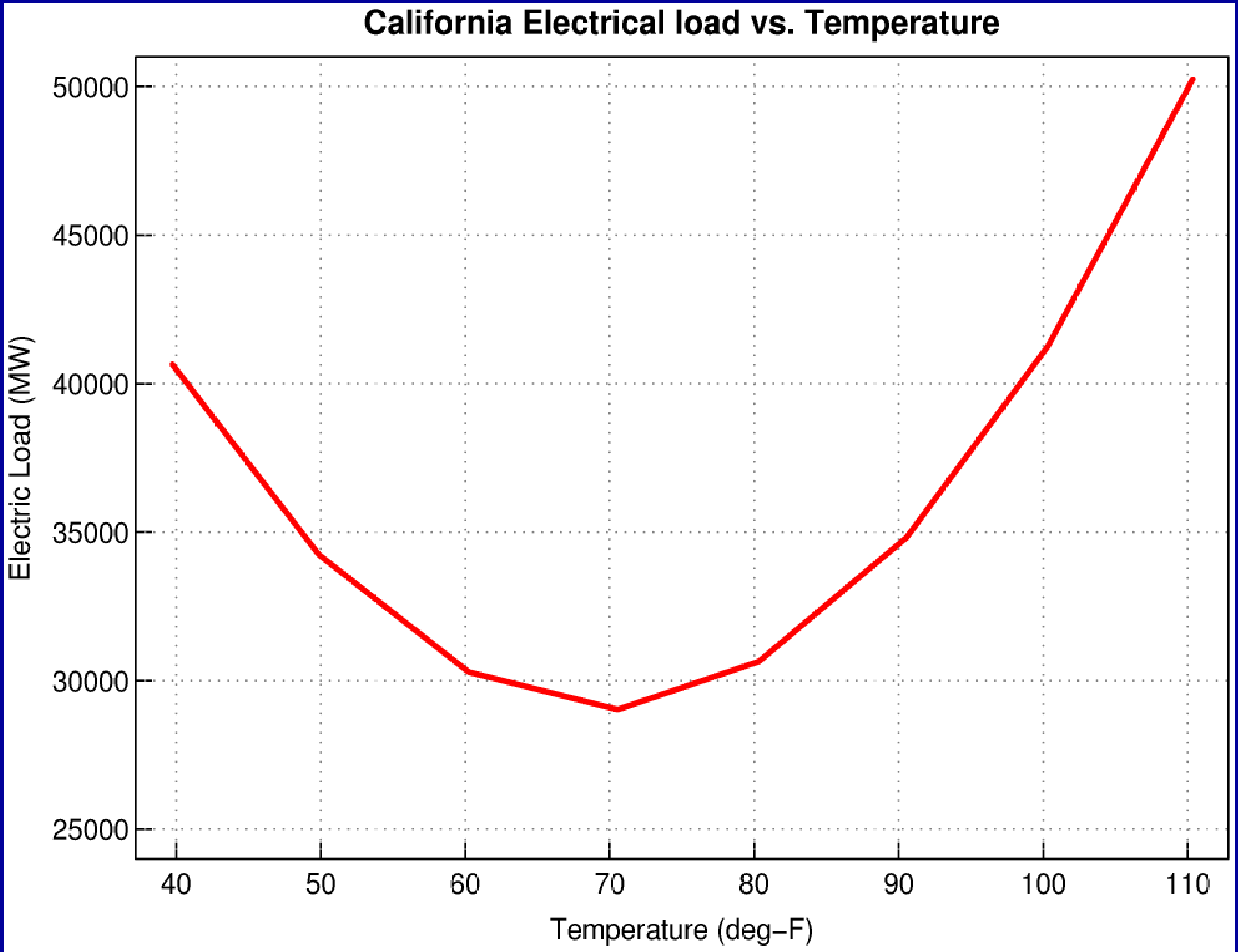


http://www.ecmwf.int/products/forecasts/d/charts/seasonal/forecast/charts/groupp/seasonal_charts_public_2tm/



Skill, CCA models
Tmean
CDD
Tmax-T90
Tmax-T95
0.4
0.35
0.3
0.25
0.2
average correlation
JFM
FMA
MAM
AMJ
MJJ
JJA
season

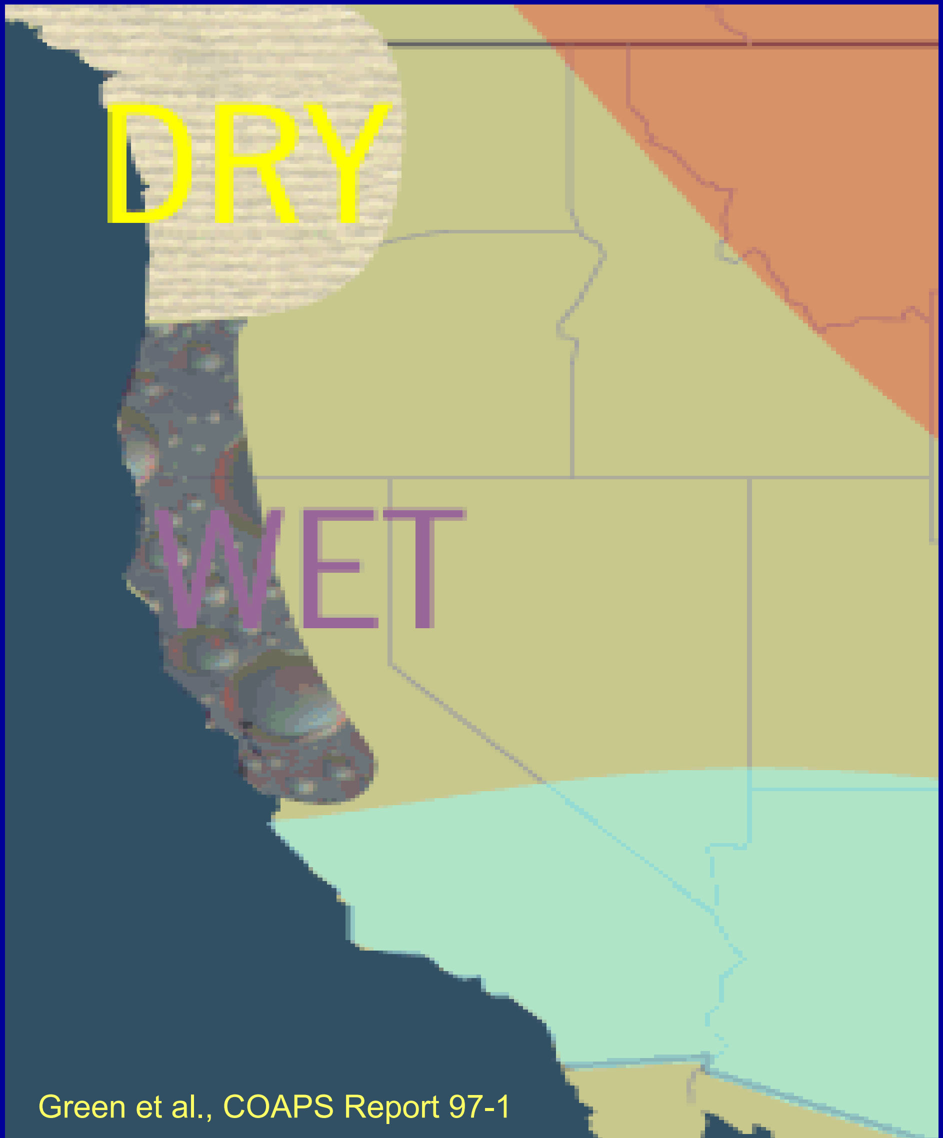
Climate & weather affect energy *demand*



On a warm summer afternoon, 40% of all electricity in California goes to air conditioning

Source: www.caiso.com/docs/0900ea6080/22/c9/09003a608022c993.pdf

…and also *supply*



Typical effects of El Nino

California imports 5-10% of its electricity from Pacific Northwest hydropower -- a dry winter over Washington can trigger higher summer electricity prices in California